SOME RECENT DEVELOPMENTS IN WATERFLOODING IN WASHINGTON COUNTY, OKLA., 1956-57

BY J. P. POWELL

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Information Circular 7787

UNITED STATES DEPARTMENT OF THE INTERIOR
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BUREAU OF MINES
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by

J. P. Powell[1/]

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1/ Petroleum engineer, Bureau of Mines, Bartlesville, Okla.

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INTRODUCTION AND SUMMARY

Systematic waterflooding was first tried in Washington County, Okla., in 1937, when a 40-acre project was begun in secs. 24, 29, 32, and 33, T. 27 N., R. 13 E., jointly by the Keener Oil Co. and the Phillips Petroleum Co. The property later was sold to Lee Morrison. A second project was begun in 1941 in sec. 14, T. 6 N., R. 12 E., by the Oklahoma Oil Corp. Both projects were abandoned by the end of 1942. A third project was begun in 1945 and the fourth in 1948, but 1949 actually was the beginning of intensive waterflooding development in Washington County. The results of previous waterflooding projects are described in Bureau of Mines Reports of Investigations.2 3 4/

Oil production in the county followed a similar trend, dropping to a low of 990,000 barrels in 1945, then steadily increasing until 1956, when more than 4 million barrels of oil was produced. Most of the increase in oil production is directly attributable to water injection.

This report presents a discussion of 4 waterflooding projects in the Bartlesville-Dewey field and 1 in the Hogshooter field (fig. 1). Four of these projects are pilot operations, but the fifth is a full-scale project with an area of 325 acres. The projects are of particular interest now because of the new methods of conditioning water and the new equipment that is being used.

One of the projects utilizes a system that completely conditions water for injection in a single tank, and requires only a small lined pond as a settling and storage basin for the aerated brine. Another utilizes an especially designed portable plant where the treating, filtering, and pumping equipment are automatically controlled and the treating and pumping unit, a laboratory, a warehouse, and tanks are mounted for moving from one pilot operation to another. A diatomaceous-earth filter also is incorporated into this compact unit. One project has a standard open water-treating system that utilizes a blower-equipped aerating tower; another project has an open-type system that uses nozzles to aerate the brine. At one treating plant, after aeration, only the new chemical additives are used to treat the water and to control corrosion.

The discussion of the individual projects that follows includes information on the source and treatment of the water used for flooding, the early production history of the properties affected, development maps of the leases, production-decline

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2/ Taliaferro, D. B., and Logan, David M., History of Waterflooding of Oil Sands in Oklahoma: Bureau of Mines Rept. of Investigations 3728, 1943, 182 pp.

3/ Riggs, C. H., and Smith, William C., Waterflooding of Oil Sands in Washington County, Okla.: Bureau of Mines Rept. of Investigations 4795, 1951, 16 pp.

4/ Powell, John P., and Johnston, Kenneth H., A Survey of Oil Production in Oklahoma by Waterflooding. Part II. Counties Other Than Nowata, Rogers, and Craig Counties: Bureau of Mines Rept. of Investigations 4832, 1951, 142 pp.

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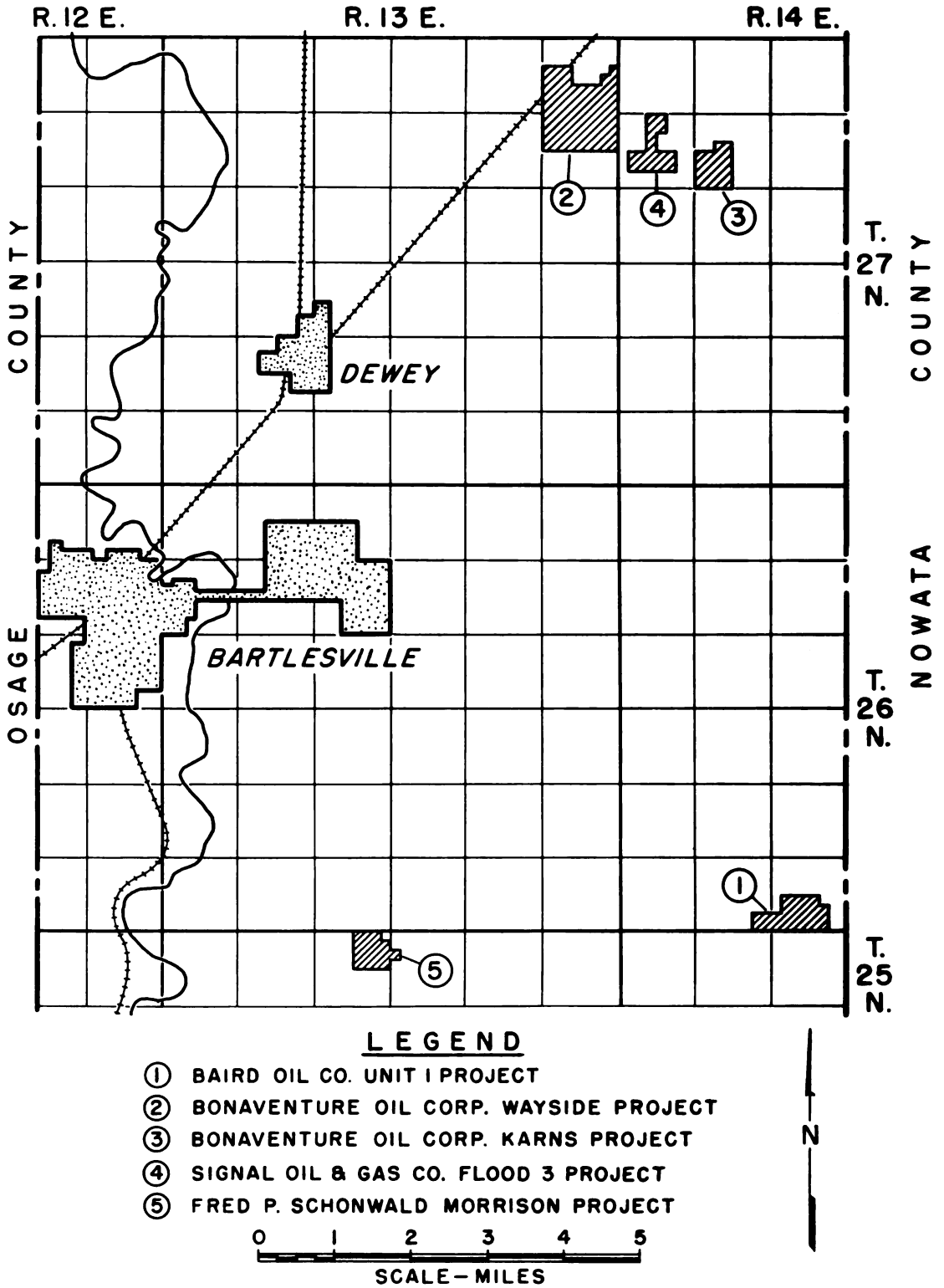

Figure 1. - Map showing locations of five waterflooding projects in Washington County, Okla., Mar. 1, 1957.

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curves, typical core analyses, analyses of raw and treated water, and sketches of water-treating plants. All the projects are too new to permit a complete analysis of the results of operation.

ACKNOWLEDGMENTS

This report on some of the recent waterflooding developments in Washington County, Okla., was prepared by the Bureau of Mines under a cooperative agreement with the State of Oklahoma.

The writer gratefully acknowledges the cooperation of the officials and employees of the oil companies and individuals operating the waterflooding projects, who made this report possible by furnishing engineering and statistical data regarding their respective projects.

The early history and much other information on the project in the Hogshooter field were obtained from data compiled by Fox.5/

DISCUSSION OF INDIVIDUAL PROJECTS

Baird Oil Co. Unit 1 Project

In 1956 the Baird Oil Co. formed its Unit 1 project from a block of leases in secs. 32 and 33, T. 26 N., R. 14 E., in the Hogshooter field, Washington County, Okla. Water injection was begun in February 1956 into 19 input wells, but drilling of the oil wells was delayed until August and September 1956. Unit 1 project includes nearly 250 acres, of which approximately 225 acres was under water flood on February 1, 1957; the 28 water-input wells and 25 oil-producing wells are arranged in 5-spot patterns; like wells are 660 feet apart. Figure 2 shows the location and areal extent of Unit 1 project and the production history of the leases.

The formation flooded is the Bartlesville sand, which is at an average depth of 1,120 feet and has an average thickness of 25 feet. Analyses of cores before flooding indicated that the formation had the following average characteristics: Porosity, 18 percent; permeability to air, 32 millidarcies; oil saturation, 27 percent; and water saturation, 38 percent. Results of a representative core analysis are shown in figure 3. The air permeability ranged from impermeable to 102 millidarcies, and the average effective permeability to water was 2.7 millidarcies. Oil produced from the formation has an API gravity of 38.8°.

History Before Flooding

These properties were developed originally between 1907 and 1912, and in 1917 vacuum was applied to wells on several leases in the unit. The rate of oil production declined gradually until 1947, when the wells were abandoned. Much of the early history and development of the leases in the Hogshooter field was described in detail by Fox and others.6/

5/ Fox, I. W., Thigpen, C. H., Ginter, R. L., and Alden, G. P., A Study of Secondary Recovery Possibilities of the Hogshooter Field, Washington County, Okla.: Federal Geol. Survey, 1944, 68 pp.

6/ Work cited in footnote 5.

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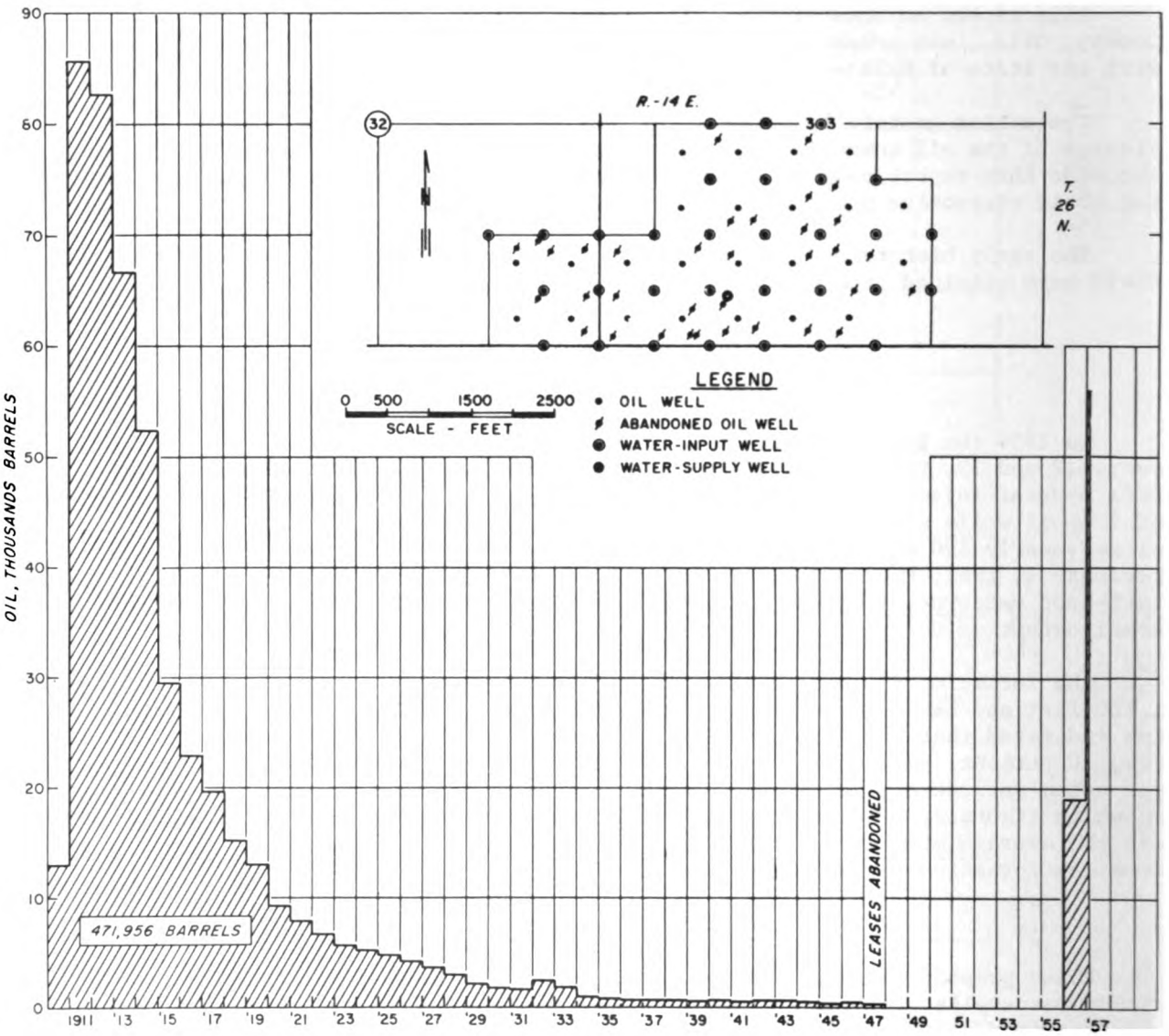

Figure 2. - Production history and map of Baird Oil Co. Unit 1, Hogshooter field, Washington County, Okla., Feb. 1, 1957.

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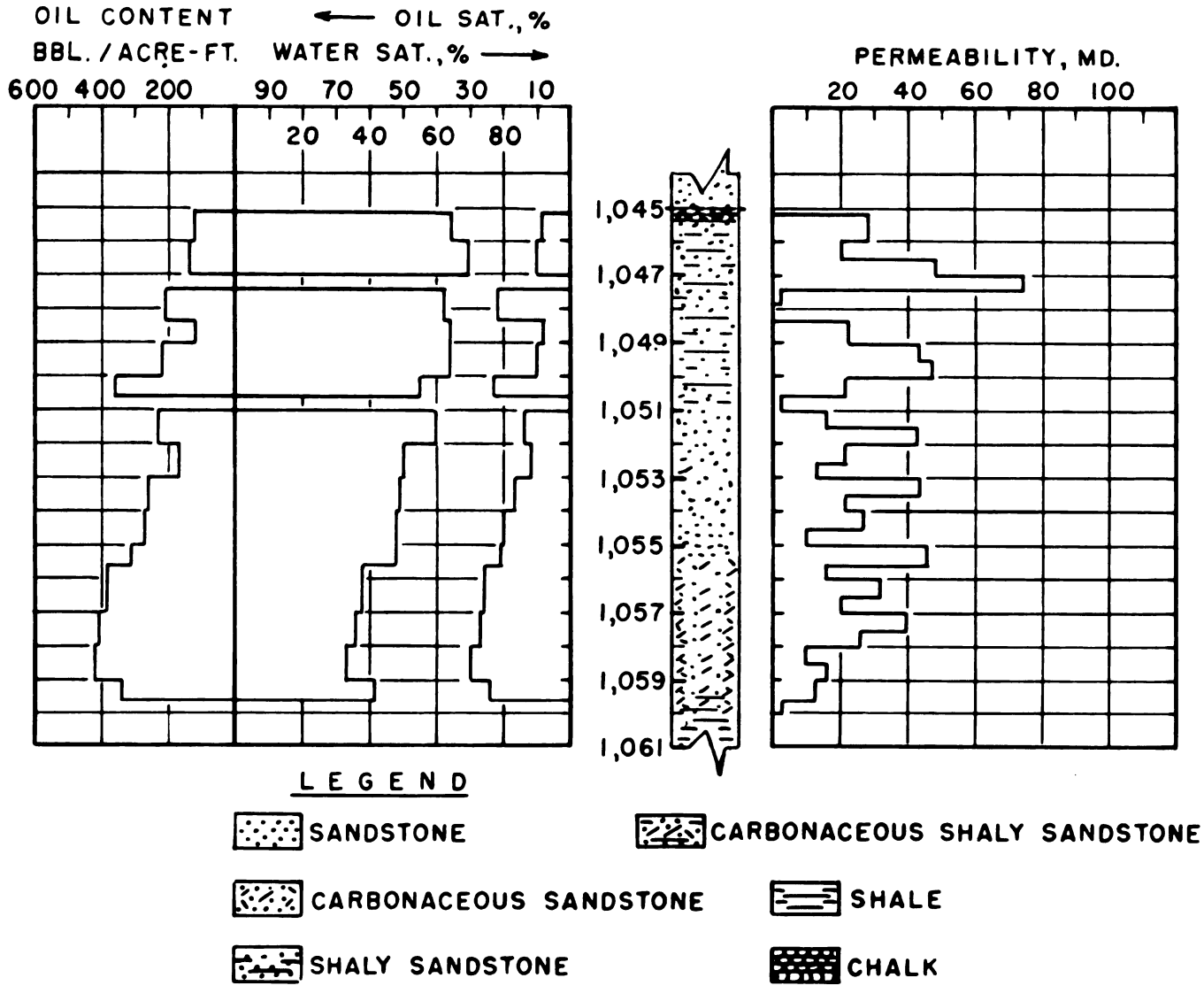

Figure 3. - Representative core analysis of Bartlesville sand, Baird Oil Co. Unit 1 project, Hogshooter field, Washington County, Okla.

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Method of Completing and Operating Wells

To prepare for waterflooding, all the old abandoned wells were reopened and plugged permanently by cementing. Several test wells also were drilled and cored before development of the unit was started.

New wells were drilled to the top of the Bartlesville sand by a rotary, then the sand was cored through and shot and completed with cable tools. Surface casing (usually 8-1/2-inch pipe, 10 to 30 feet long) was set and cemented to protect shallow water sands. A 6-5/8-inch hole then was drilled to the top of the sand at a depth of about 1,110 feet. A core barrel was inserted and the formation cored to enable the operator by inspection to locate precisely any gas sand, coal streaks, or fractures in the top of the formation, so as to shoot and to set pipe to the best advantage. After coring, the drilling mud was thinned with water, and each well was shot with approximately 1 quart of nitroglycerin per foot of pay sand. The well then was cleaned out and washed thoroughly, after which the casing was set and cemented with enough sacks of cement (45 to 60) to shut off the water from the Oswego limestone formation.

After the cement had set, the plug was drilled out with cable tools, and the well bore again was washed until clean. The final washing included mud acid (approximately 1 barrel), which was left in the well overnight and then was bailed out. When the well was clean, surface equipment, such as meter and control valves, was connected, and water injection was begun. An orifice plate was used at each input well to aid in controlling the rate of injection.

The same procedure was followed for oil-producing wells, except that tubing and rods were run and electrically operated pumping units were installed for pumping the well.

Source and Treatment of Water

Brine for flooding is obtained from a supply well, completed at a depth of 1,807 feet in the Arbuckle limestone with 6-5/8-inch casing set and cemented at 1,708 feet at the top of the Arbuckle limestone. A 30-hp. submersible electric pump on 2-inch steel tubing is set at 760 feet and delivers brine to the surface, thence through 3-inch plastic surface pipe to the header at the aeration pond. The static water level of the well is 180 feet below ground level; when the pump is operating, the level is drawn down 270 feet to a subsurface depth of 450 feet.

Figure 4 shows the water-treating plant of the Baird Oil Co. Unit 1 project. The brine produced with the oil is separated and collected in a central tank-battery near the aeration pond and flows from the separator into a 600-barrel skimming pond to remove any oil remaining in the brine. The skimming pond is divided into two sections by an earthen baffle, and the water flows from the upper into the lower section through a 4-inch pipe in the middle of the baffle. The pipe is submerged in the upper section of the pond and exposed in the lower section; this provides for skimming the oil and some aeration of the water. The lower section of the pond provides further skimming to prevent any remaining oil from entering the water-treating system. The produced brine flows from the skimming pond through a 4-inch pipe into the aeration pond, where it commingles with the aerated Arbuckle brine.

The aeration pond, which is 75 by 140 by 5 feet deep, is riprapped to minimize erosion of the dirt sides by wind and wave action. The pond is divided in the center by a wooden trestle, which supports a 4-inch plastic-pipe header that discharges

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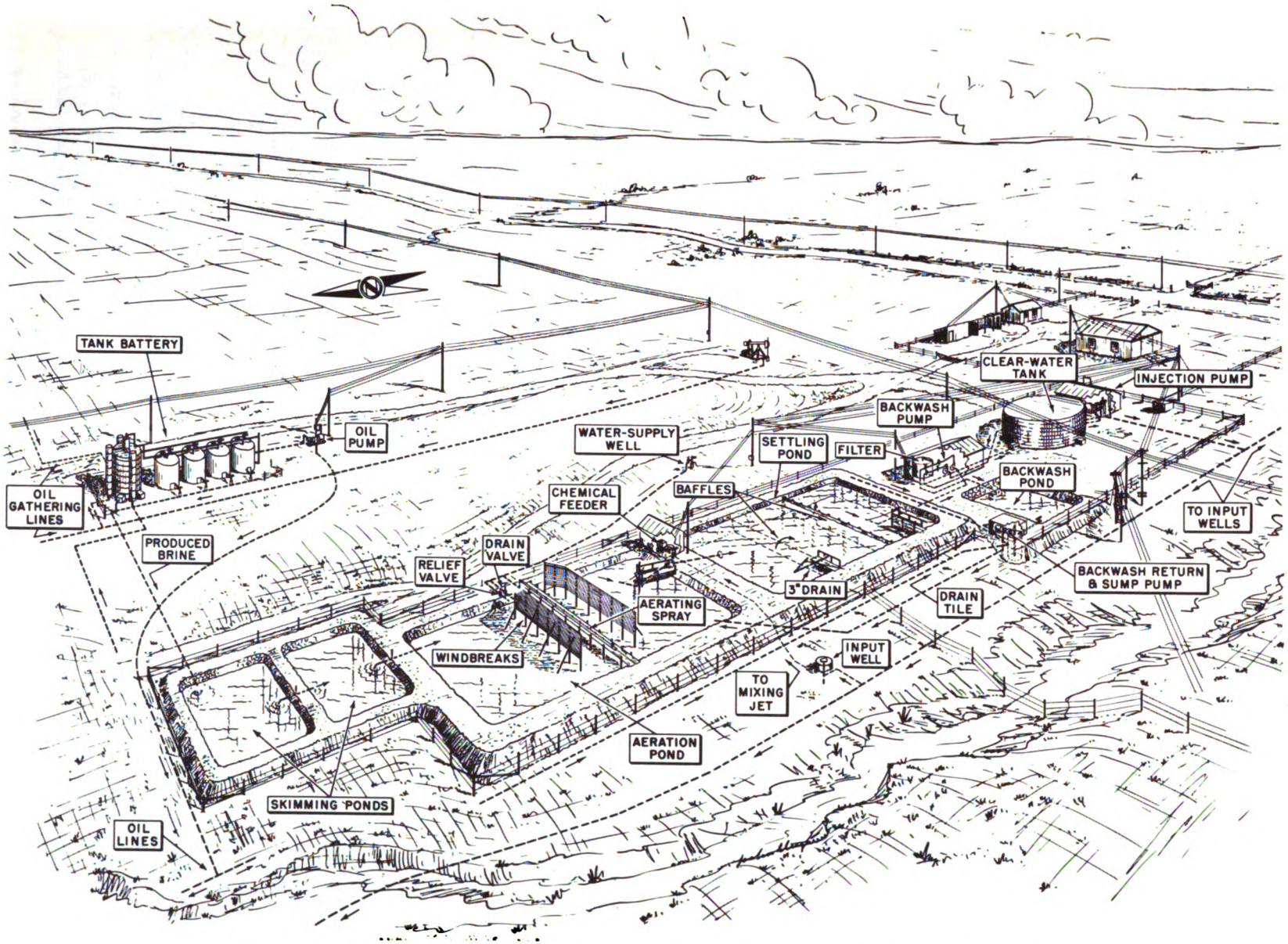

Figure 4. - Water-treating plant of Baird Oil Co. Unit 1 project, Washington County, Okla.

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water from the supply well at a pressure of 25 p.s.i. through 12 plastic spray nozzles set about 18 inches apart along the header. Each nozzle is approximately 4 inches long. Wooden baffles on each side of the header minimize the loss of water by evaporation and spray.

From the aeration pond the water flows through an 8-inch pipe into the chemical treater, where chemicals are added by an electrically driven dry feeder. In January (1957) only lime was added for water treatment; however, during the hot summer months copper sulfate is added to minimize the growth of bacteria. The dry chemicals are fed (at a rate proportional to the flow of water) into a mixing tank, where a stream of water jetted into the tank aids mixing and solution of the chemicals.

The treated water flows into a settling pond, 75 by 140 by 5 feet deep, and is divided into sections by baffles - 1 "over" and 1 "under" baffle - which are constructed of corrugated cement-asbestos sheets pinned to wooden posts. An automatic float control in the settling pond actuates the water-supply pump to maintain an adequate supply of treated water.

The water is pumped by a 1-1/2- by 2-inch Mission centrifugal pump from the settling pond to the clear-water tank through a closed pressure filter, using a mixture of graded sand and gravel as a filter medium. The filter is backwashed when it is necessary with water from the clear-water tank by a 3- by 4-inch Mission centrifugal pump powered by a 7.5-hp. electric motor.

The clear-water tank is a covered 1,600-barrel wooden tank about 20 feet high. A float on the tank automatically controls the pump, which forces water through the filter to maintain a minimum head of 10 feet of water on the intake of the pressure pump.

Backwash water from the filter flows into a settling pond, where the dirt is allowed to settle, and then the cleaned water is pumped back into the aeration pond by an electrically driven sump pump. Results of analyses of samples of the treated and untreated brines are shown in table 1.

TABLE 1. - Mineral analyses of injection waters, Baird Oil Co. Unit 1 project, Washington County, Okla.

	Supply-well water		Produced brine		Mixed brine, untreated		Clear well water	
Radical	p.p.m.	Reacting values, percent (Palmer)	p.p.m.	Reacting values, percent (Palmer)	p.p.m.	Reacting values, percent (Palmer)	p.p.m.	Reacting values percent (Palmer)
Calcium (Ca)	3,800	6.51	4,400	6.35	3,900	6.39	3,800	6.72
Magnesium (Mg)	1,250	3.53	1,400	3.33	1,300	3.51	1,250	3.56
Sodium (Na)	26,800	39.96	32,100	40.33	28,100	40.10	26,300	39.72
Carbonate (CO_3)	0	0	0	0	0	0	24	.03
Bicarbonate (HCO_3)..	378	.21	238	.10	220	.11	51	.03
Sulfate (SO_4)	0	0	148	.10	68	.05	79	.06
Chloride (Cl)	51,400	49.79	61,100	49.80	53,800	49.84	51,000	49.89
Total solids ..	83,628	100.00	99,386	100.00	87,388	100.00	82,584	100.00
Hydrogen sulfide (H_2S)	Present		None		None		None	
Barium (Ba)	16 p.p.m.		24 p.p.m.		27 p.p.m.		14 p.p.m.	
Specific gravity ...	1.059		1.063		1.062		1.061	

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A 3- by 6-inch Wheatley, double-acting, duplex pump, driven by a 30-hp. electric motor, pumps the water through the distribution lines to the input wells at a plant pressure of 500 p.s.i. Cement-lined pipe is used in the water-distribution lines and plastic pipe in the produced oil- and water-gathering lines. A corrosion inhibitor (Visco 983) is added to the water to reduce corrosion. Approximately 4 gallons of inhibitor per week is added to the raw water by pouring 1 gallon every other day into the annulus of the Arbuckle supply well.

Results of Flooding

To February 1, 1957, nearly 23,690 additional barrels of oil was recovered from the 225 developed acres by injecting 261,638 barrels of water, water-injected:oil-produced ratio of 11:1 and a recovery of 105 barrels per acre.

Drilling of the oil wells was delayed for almost 6 months after water injection was begun. After completion of the first oil well, a flow of water was encountered; this was very disturbing, and the water-pumping plant was shut down temporarily until the situation could be investigated. Tests indicated that water from an upper formation had entered the pay sand through an abandoned well. During development of the project, several other wells have behaved similarly, but continuous pumping is exhausting this water. Most of the oil wells affected by the planned water drive have a low water cut.

As approximately only 9,000 barrels of water per well has been injected into the formation, it is presumed that the reservoir voids have not been completely filled, and it is believed that better results will be obtained when this has been accomplished.

Summary of Operations

Baird Oil Co. Unit 1 project
Hogshooter field, Washington County, Okla.

Location - sec. 32 and 33, T. 26, N., R. 14 E.
Sand flooded - Bartlesville.
Depth to top of sand - 1,120 feet.
Average sand thickness - 25 feet.
Productive area - 250 acres.
Area flooded - 225 acres.
Well pattern - 5-spot (660 x 660 ft.).
Type of water - brine.
Type of system - open.
First injection - Feb. 16, 1956.
First oil increase - August 1956.
Status - active.
Gravity of oil - 38.8° API.
Viscosity of oil - 4.2 cp. at 100° F.

Oil production, by years, bbl.
(Unit 1 leases, 280 acres)

1910 12,973	1920 9,344	1930 1,895	1940 785
1911 85,790	1921 7,984	1931 1,729	1941 646
1912 82,728	1922 6,705	1932 2,586	1942 747
1913 66,736	1923 5,736	1933 1,940	1943 713
1914 52,410	1924 5,198	1934 1,009	1944 521
1915 29,544	1925 4,845	1935 842	1945 474
1916 22,942	1926 4,279	1936 794	1946 573
1917 19,692	1927 3,731	1937 733	1947[1] 312
1918 15,296	1928 3,066	1938 722	1956[2] 19,016
1919 13,017	1929 2,237	1939 682	1957 .....[3] 4,674

1/ Lease abandoned.
2/ Waterflooding begun (250 acres).
3/ January's production.

	Bbl.
Oil recovered before waterflooding (280 acres)	471,956
Recovery per acre before waterflooding (280 acres)	1,686

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Summary of waterflood performance

Date	Acres flooded	Active water wells	Active oil wells	Oil recovery, bbl. per acre	Cumulative water-injected: oil-produced ratio
August 31, 1955	100	28	10	16	64
September 30, 1955	225	28	24	24	24
October 31, 1955	225	28	24	43	17
November 30, 1955	225	28	24	65	13
December 31, 1955	225	28	24	85	12
January 31, 1956	225	28	24	105	11

	Bbl.
Water injected to February 1, 1957	261,638
Oil recovered to February 1, 1957	23,690

Monthly record of water injected and oil produced, bbl.

	1956		1957	
	Water injected	Oil produced	Water injected	Oil produced
January	-	-	32,493	4,674
February	914	-		
March	-	-		
April	19,824	-		
May	30,839	-		
June	22,133	-		
July	-	-		
August	27,231	1,576		
September	28,002	3,863		
October	32,982	4,228		
November	33,141	4,853		
December	34,079	4,496		
Total	229,145	19,016	32,493	4,674

Bonaventure Oil Corp. Wayside Project

In April 1953 the Bonaventure Oil Corp. began injecting water into a 50-acre pilot project in secs. 1 and 12, T. 27 N., R. 13 E., in the Wayside pool, Washington County, Okla. When the pilot operation proved successful, the project was expanded and now includes 325 acres in secs. 1 and 12. Approximately 1,080 acres is under lease in the area and additional water-treating and pumping plants will be constructed as more acreage is developed. A map of the flood area is shown in figure 5.

The formation flooded is the Wayside sand, which in this area has the following average characteristics: Depth, 500 feet; thickness, 25 feet; porosity of oil sand, 21 percent and permeability, 33 millidarcies; oil saturation, cores, 25 percent; and water saturation, 45 percent. The API gravity of the oil is 32°. Results of a representative core analysis are shown in figure 6.

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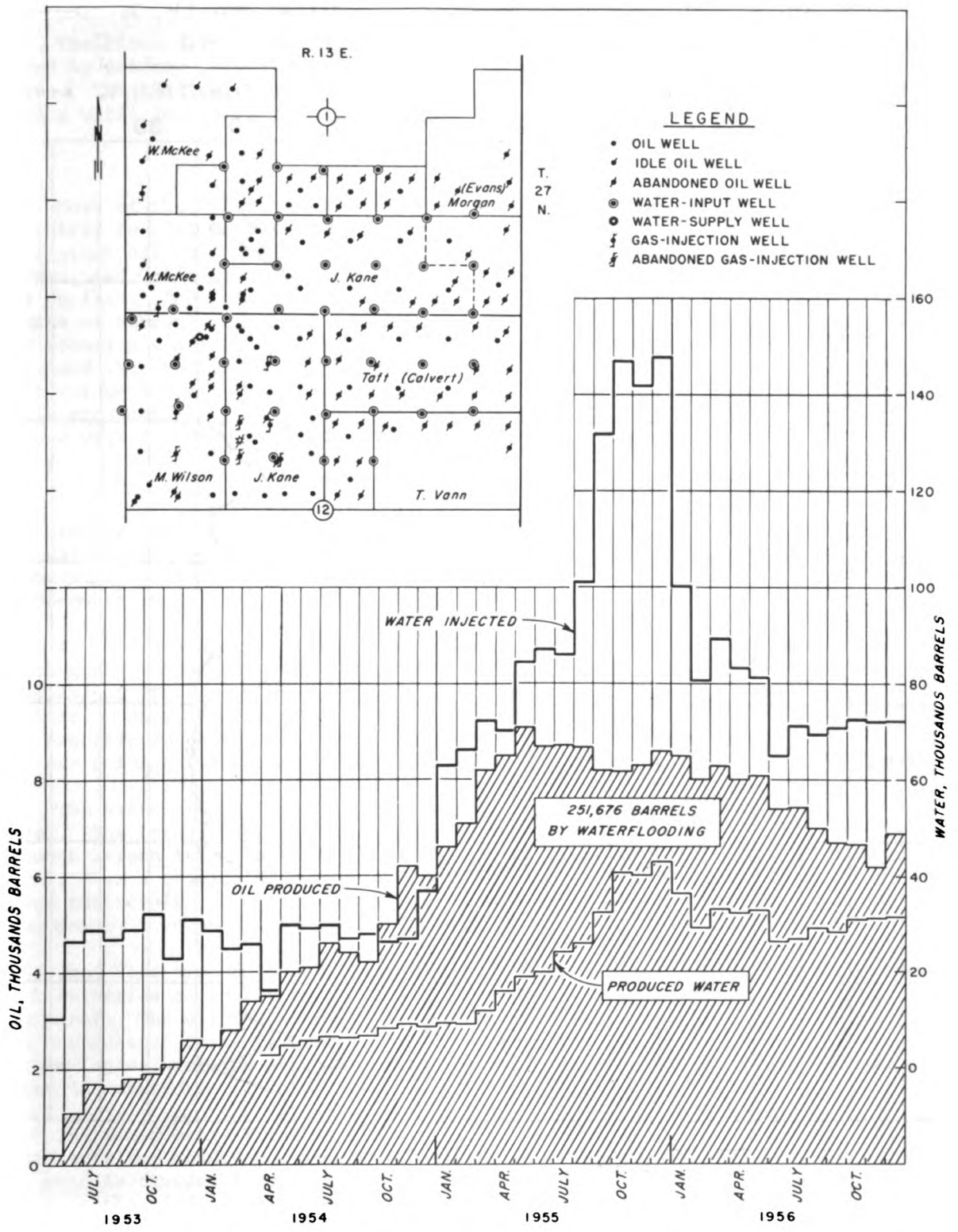

Figure 5. - Waterflood production history and map of Bonaventure Oil Corp. Wayside project, Wayside field, Washington County, Okla., Jan. 1, 1957.

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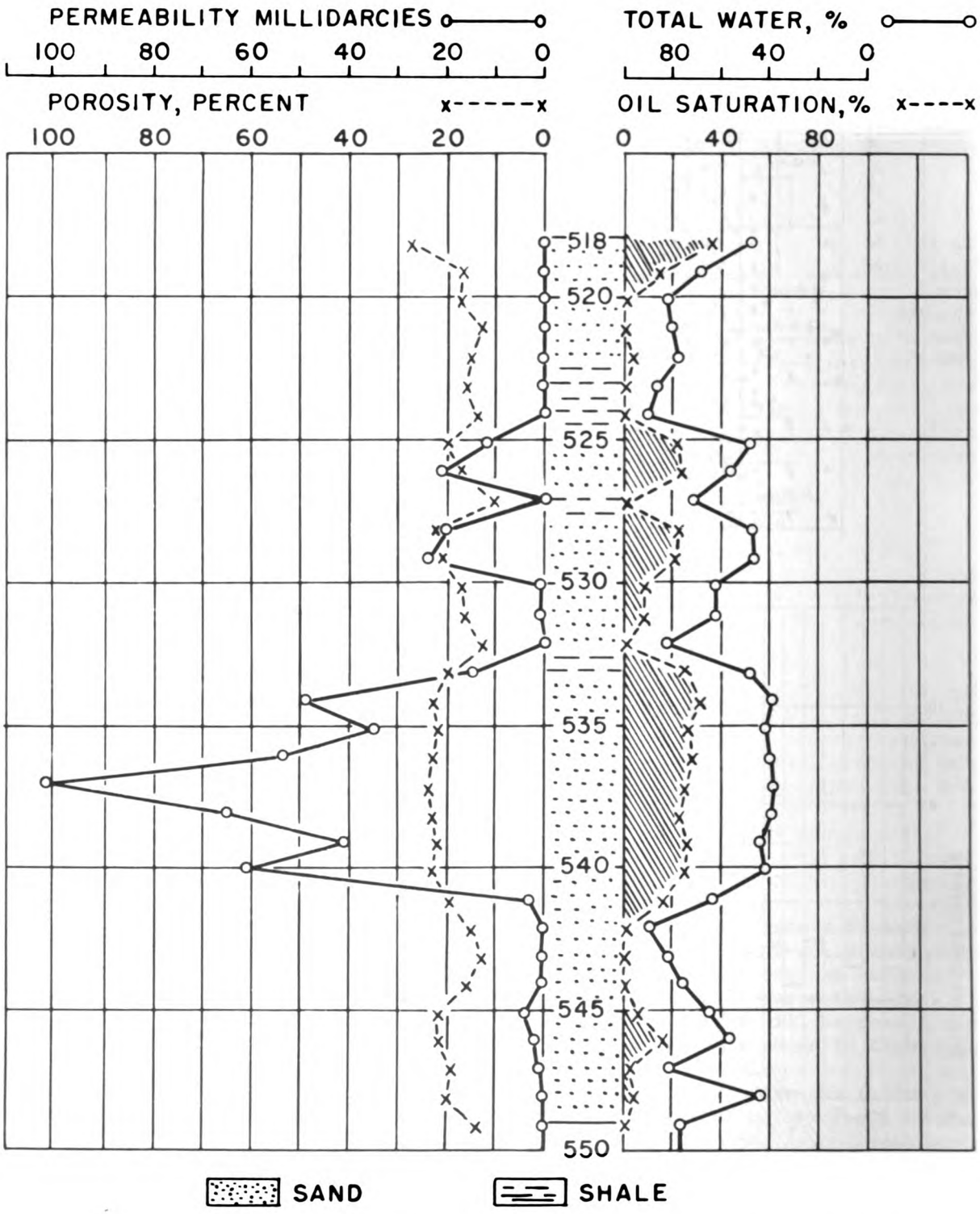

Figure 6. - Representative core analysis of Wayside sand, Bonaventure Oil Corp. Wayside project, Wayside field, Washington County, Okla.

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History Before Flooding

The flooded leases were drilled originally in 1907 and 1911, and oil was produced by primary methods until the mid-thirties, when the use of gas injection was begun. The gas-injection operation was not carried on intensively but was continued until just before water injection was begun.

Method of Completing and Operating Wells

Most of the wells, both inputs and producers, were drilled by a rotary. Twenty to thirty feet of 7-inch surface pipe was set for each well and cemented, and a 6-1/4-inch hole was drilled to the top of the sand. The formation was cored and reamed, and 4-1/2-inch pipe was set at the top of the Wayside sand and cemented to the surface. Some of the wells were shot with marble shots, others with 1 to 1-1/2 quarts of nitroglycerin per foot of pay sand. After shooting, the cement plug used for stemming was drilled out with cable tools, the formation washed down and cleaned out, and the well equipped either as a producing or an input well. Surface equipment for each input well consists of a meter and control valves. The producing wells are equipped with 5/8-inch rods, 2-inch tubing, and a working barrel and are pumped with individual electrically powered pumping units controlled by time clocks.

Source and Treatment of Water

During the first 20 months of pilot operation, a closed water-conditioning system was used. However, as the volume of produced brine increased, it was considered economical to convert to an open-type treating system. The conversion was completed in December 1954.

A well completed in the Arbuckle formation supplies brine for the flood. After setting about 50 feet of 8-inch surface pipe, the well was drilled to the top of the Mississippi limestone, where 1,282 feet of 7-inch casing was set and cemented to the surface. Later, a 5-1/2-inch liner was set and cemented at 1,487 feet at the top of the Arbuckle formation. The well then was drilled to a total depth of 2,097 feet and was acidized with 5,000 gallons of acid.

The static fluid level of the Arbuckle brine is about 230 feet below ground level. The brine is lifted from the well by a 50-hp. submersible electric pump through 3-inch tubing and pumped to the top of a wooden tray-type aerating tower. Figure 7 is a drawing of the water-treating plant at the Wayside project. Table 2 gives the results of mineral analyses of samples of the raw and treated water taken from points throughout the system.

The brine produced with the oil also is used in the flood and is piped from the tank batteries on the separate leases to a buried skimming tank at the water-treating plant. The oil is separated ans siphoned from the tank into a nearby well, and the accumulated brine is pumped periodically to the top of the aerating tower, where it commingles with the Arbuckle brine for aeration and contitioning. The produced brine is metered as it is pumped from the tank.

The mixed brine flows from the aerating tower into a large (180- by 160- by 8-foot) settling pond, where the solids produced by aeration are permitted to settle. The pond is divided into three sections by "over" and "under" baffles. The water level in the pond is maintained at constant height by a float-actuated switch that controls the pump in the supply well. Aerated brine flows from the settling pond by gravity through a concrete-block flume through the chemical treater, where chemicals

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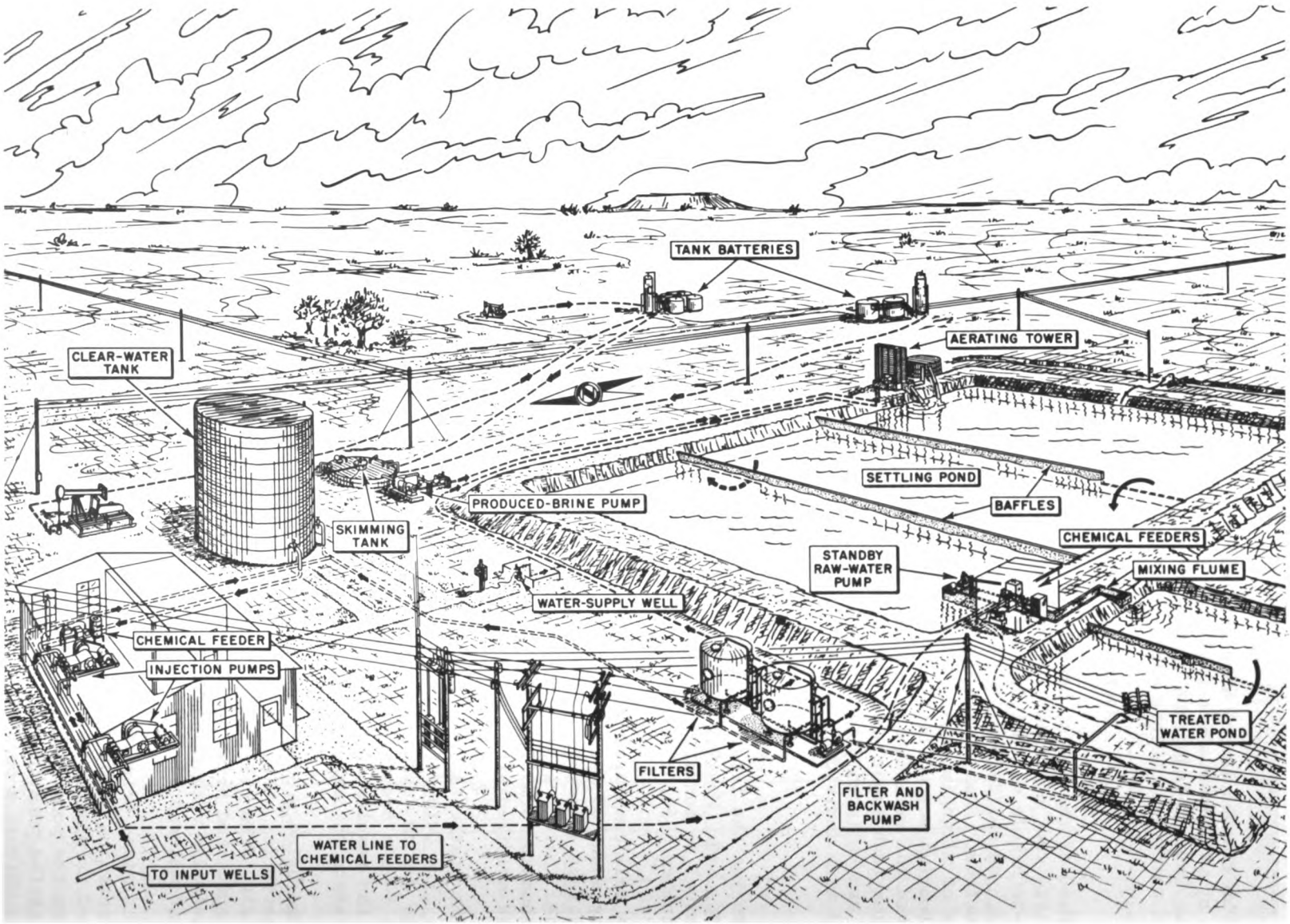

Figure 7. - Water-treating plant of Bonaventure Oil Corp. Wayside project, Washington County, Okla.

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are added. A centrifugal pump, powered by a 10-hp. electric motor at the inlet end of the flume, is used to pump water through the chemical treater when the pump must be serviced and the water level in the pond drops too low to allow flow by gravity.

TABLE 2. - Mineral analyses of injection waters, Bonaventure Oil Corp. Wayside project, Washington County, Okla.

	Supply-well water		Produced brine		Clear well water	
Radical	p.p.m.	Reacting values, percent (Palmer)	p.p.m.	Reacting values, percent (Palmer)	p.p.m.	Reacting values, percent (Palmer)
Calcium (Ca)	4,900	7.05	5,000	6.92	5,000	7.17
Magnesium (Mg)	1,500	3.55	1,700	3.87	1,750	4.13
Sodium (Na)	31,300	39.40	32,500	39.21	30,100	38.70
Carbonate (CO_3)	0	0	0	0	0	0
Bicarbonate (HCO_3)	347	.16	165	.08	122	.06
Sulfate (SO_4)	trace	-	88	.05	88	.05
Chloride (Cl)	61,300	49.84	63,800	49.87	61,600	49.89
Total solids	99,347	100.00	103,253	100.00	98,600	100.00
Hydrogen sulfide (H_2S)	Present		None detected		None detected	
Barium (Ba)	12 p.p.m.		70 p.p.m.		5 p.p.m.	
Specific gravity	1.073		1.068		1.072	

Lime and other chemicals prepared by the Treatrite Chemical Co. are added to the water in the flume by two dry chemical feeders, each of which is powered by a 1/4-hp. electric motor. As the water flows from the chemical treater through the Z-shaped flume leading to the settling pond, it is agitated by small baffles of concrete blocks placed at intervals along the flume; this agitation aids mixing and solution of the chemicals in the water. The small settling pond (60 by 75 by 8 feet) into which the water flows after the chemicals are added allows the water to stand long enough for the chemical reaction to be completed and for surplus chemicals and precipitates to settle. The pond has "end-around" baffles that prolong the retention time.

An Aurora centrifugal pump, powered by a 10-hp. electric motor, forces water from the settling pond through two parallel, closed pressure filters, using sand as a filter medium. A small chemical-proportioning pump injects 3 pounds of citric acid into the intake of the filter pump. The filters are backwashed when necessary by pumping water with the Aurora filter pump from the settling pond in reverse flow through the filters into the aeration pond. Filtered water is stored in a 500-barrel wooden clear-water tank, which is connected to the intake of an Oilwell 344 pump driven by a 50-hp. electric motor. A second pump and motor now serving on a standby basis will be used when the project is expanded. A small chemical pump in the plant injects 2 to 2-1/2 gallons of X-cide 333 (a corrosion inhibitor) into the intake of the injection pump. Water enters the distribution system at a plant pressure of 450 p.s.i.

Results of Flooding

Good results have been achieved on this project during the short period of its operation (fig. 5). More than 251,000 additional barrels of oil has been recovered from the 325 flooded acres by injecting 2.7 million barrels of water. This is a

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water-injected:oil-produced ratio of 11:1. An increase in the rate of oil production was noted early because many of the old wells were retained for test purposes; they are included in the unusually large number of active wells shown in the Summary of Operations. Some channeling of the injected water has occured, but a reduction in plant pressure seems to minimize the effect.

Summary of Operations

Bonaventure Oil Corp. Wayside project
Wayside field, Washington County, Okla.

Location - secs. 1, 2, 11, and 12, T. 27 N., R. 13 E.
Sand flooded - Wayside.
Depth to top of sand - 500 feet.
Average sand thickness - 25 feet.
Productive acres - 1,080 acres.
Area flooded - 325 acres.
Well pattern - 5-spot (660 x 660 ft.).
Type of water - brine.
Type of system - open.
First water injection - April 1953.
First oil increase - May 1953.
Status - active.
Gravity of oil - 32° API.
Viscosity of oil - 13.8 cp. at 60° F.

Primary production data

(Not available.)

Summary of waterflood performance

Date	Acres flooded	Active input wells	Active oil wells	Oil recovery, bbl. per acre	Cumulative water-injected: oil-produced ratio
December 31, 1953	50	11	11	264	16
December 31, 1954	120	20	36	540	8
December 31, 1955	260	38	47	624	11
December 31, 1956	325	44	69	774	11

	Bbl.
Water injected to January 1, 1957	2,678,978
Oil recovered by waterflooding to January 1, 1957	251,676
Water produced to January 1, 1957	725,186

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Monthly record of water injected and oil produced, bbl.

	1953			1954		
	Water injected	Oil produced	Water produced	Water injected	Oil produced	Water produced
January				28,840	2,521	
February				25,103	2,835	
March				26,136	3,484	
April				16,582	3,501	2,891
May	1/ 10,564	224		30,001	4,032	4,899
June	26,718	1,127		29,444	4,133	5,905
July	29,054	1,722		30,019	4,689	6,541
August	27,313	1,637		27,339	4,471	6,444
September	29,057	1,826		28,068	4,291	6,750
October	32,486	1,902		26,624	5,285	8,270
November	23,317	2,143		27,006	6,279	9,166
December	31,597	2,603		37,814	6,088	8,659
Total	210,106	13,184		332,976	51,609	59,525
	1955			1956		
January	63,681	6,608	9,665	100,525	8,571	36,697
February	66,480	7,123	9,377	80,807	8,023	29,622
March	72,532	8,228	12,023	89,931	8,355	33,469
April	71,595	8,511	16,090	83,773	8,034	32,763
May	84,781	7,171	19,108	81,714	8,162	33,031
June	87,766	8,743	20,036	65,698	7,420	26,375
July	86,286	8,792	24,395	71,867	7,453	27,275
August	101,439	8,710	26,009	69,979	7,058	29,385
September	132,174	8,258	32,665	71,241	6,716	28,662
October	147,480	8,220	40,694	72,995	6,708	31,139
November	142,261	8,328	40,336	72,385	6,277	31,725
December	148,037	8,627	43,136	70,469	6,787	31,984
Total	1,204,512	97,319	293,534	931,384	89,564	372,127

1/ Includes 2 days water injected during April.

Bonaventure Oil Corp. Karns Project

In November 1956 the Bonaventure Oil Corp. began constructing a water-treating plant on the Karns project in sec. 8, T. 27 N., R. 14 E., Washington County, Okla., to test the floodability of the Bartlesville sand in that area. Figure 8 is a map of the pilot-project area (30 acres flooded). One of the outstanding features of the project is the use of a National Tank Co. raw-water treating system. Figure 9 is a drawing of the treating plant.

The Bartlesville sand in this area is at an average depth of 1,130 feet and has an average thickness of 20 feet. The sand is not continuously oil-productive; it exists as small lenses, which grade laterally into shale or an impermeable sand. Several wells have been cored, and the cores were found to have the following average characteristics: Porosity, 19 percent; permeability, 15 millidarcies; oil saturation, 32 percent; and water saturation, 38 percent. The API gravity of the oil is 36°. Figure 10 is a core graph typical of several core analyses.

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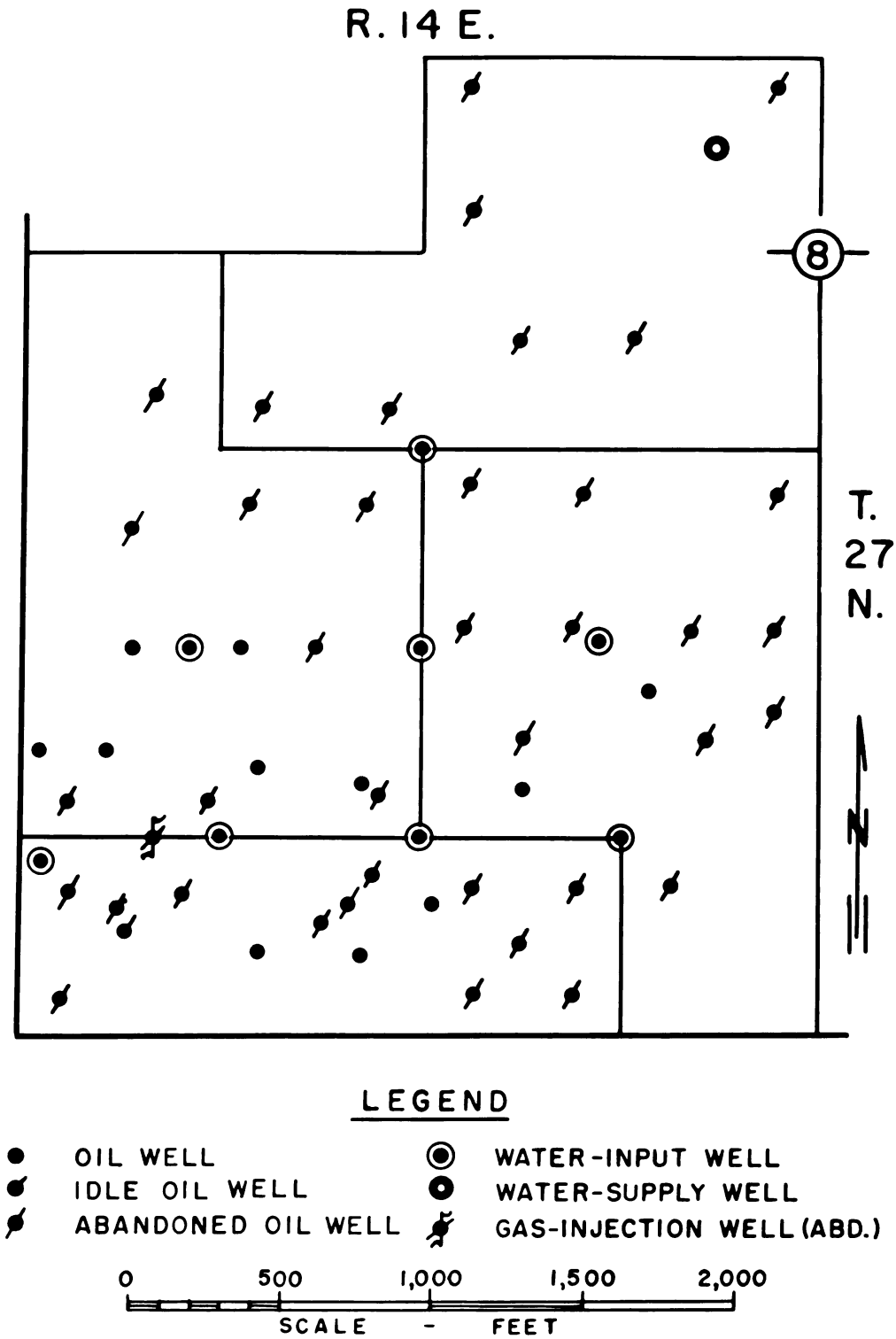

Figure 8. - Pilot-flood area, Bonaventure Oil Corp. Karns project, Wayside field, Washington County, Okla., Mar. 1, 1957.

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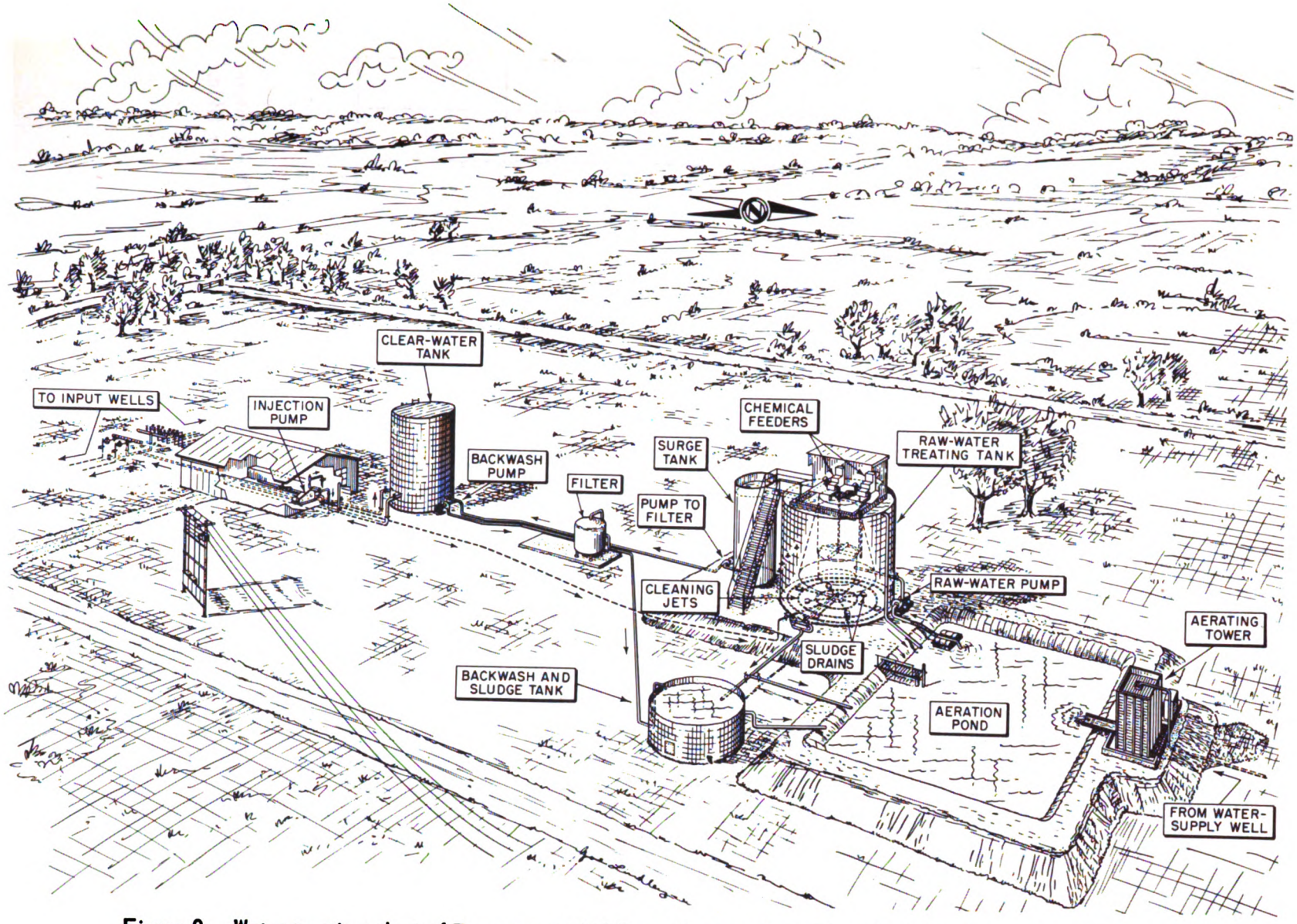

Figure 9. - Water-treating plant of Bonaventure Oil Corp. Karns project, Wayside field, Washington County, Okla.

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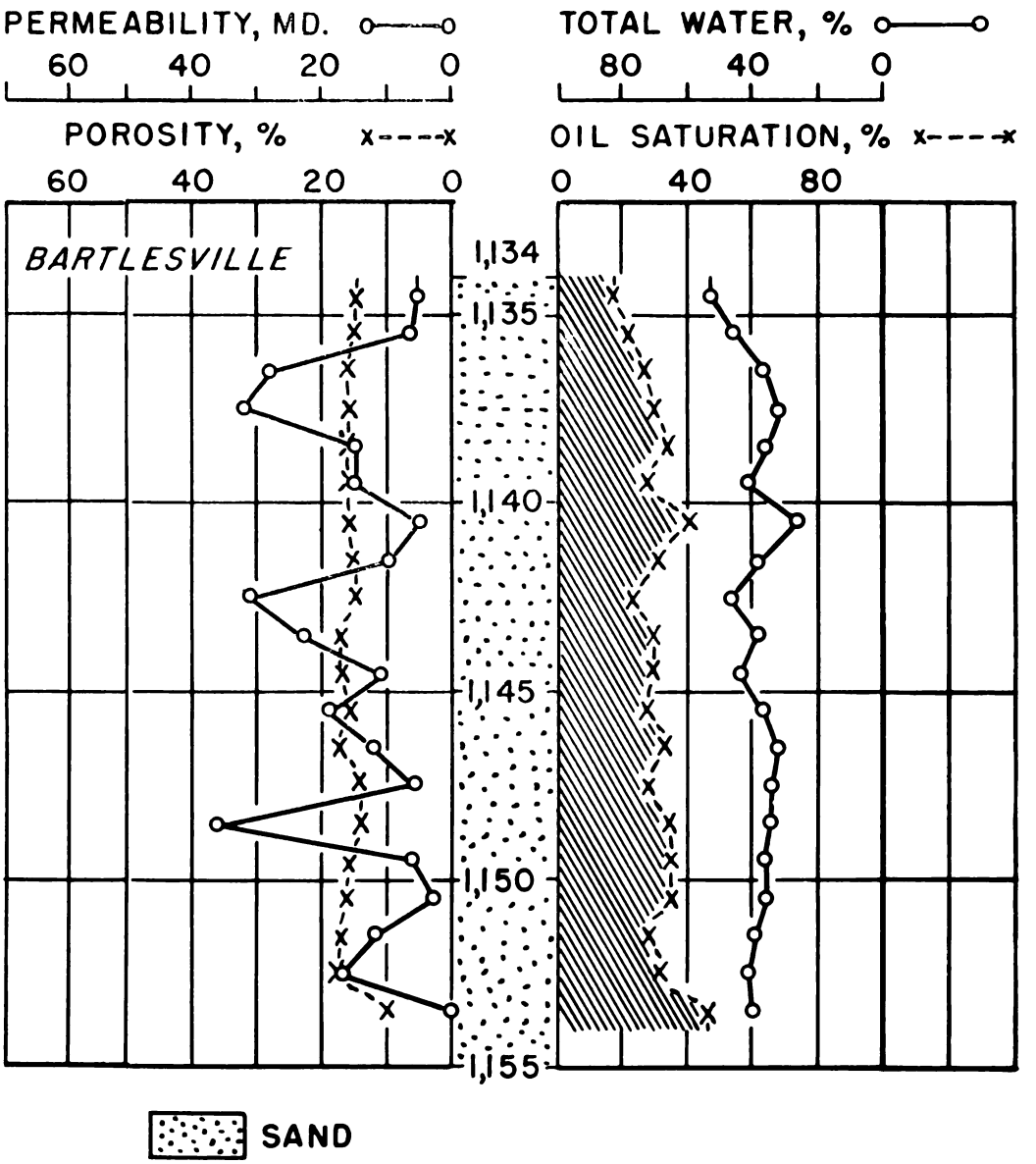

Figure 10. - Representative core analysis of Bartlesville sand, Bonaventure Oil Corp. Karns project, Wayside field, Washington County, Okla.

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History Before Flooding

The property was drilled originally in 1916 and 1917, and production was from the Wayside sand as well as the Bartlesville sand. Primary methods of production were used until the 1940's when a gas well was completed in the Burgess sand. Gas from this well was injected through several wells into the Bartlesville sand at pressures of 30 to 40 p.s.i. until February 1957, when water injection was begun.

Method of Completing and Operating Wells

The input wells were drilled by a rotary. A 6-1/4-inch hole was drilled to the top of the oil-producing formation, and the sand was cored and then shot with 2 quarts of nitroglycerin per foot of pay sand. A Calseal plug was used for stemming the shot, which was detonated by a time bomb. After the shot, 4-1/2-inch pipe was set on top of the Bartlesville sand and cemented to the surface. The plug was drilled out later with cable tools, and the well was cleaned out, conditioned, and equipped for water injection. Meters, control valves, and pressure cocks for all the test wells are located centrally near the water-pumping plant. About 300 gallons of kerosine is pumped into each input well before water is injected. Water injection was not begun until February 1957.

No new producing wells have been drilled to complete the five-spot pattern, although some of the old wells have been left for testing purposes.

Source and Treatment of Water

A well drilled to a total depth of 2,298 feet through the water-bearing strata of the Arbuckle formation into the granite supplies water for the pilot flood. This well was completed with 7-inch casing set and cemented at 1,734 feet at the top of the Arbuckle limestone; the open hole was cleaned out and the stratum was acidized with 10,000 gallons of Dowell X acid. The brine is lifted with a 30-hp. electric submersible pump through 2-1/2-inch tubing set at 820 feet and is forced to the top of a 10-foot-high, wooden, tray-type aerating tower. Air is forced through the tower by an electrically driven blower to provide better aeration. The aerated brine flows from the tower into a lined settling pond, where the suspended solids are allowed to settle. Water is forced from the settling pond into the raw-water treating tank by a Gould electrically driven centrifugal pump. The water enters the tank in a central flume, where chemicals are added and mixed by an impeller to form a slurry. The impeller forces the brine slurry up through the flume and then down through a hood into a precipitation zone. The heavy precipitates are withdrawn automatically and jetted into the backwash and sludge tank. The treated brine separates from the sludge and flows into a collector ring and then into the surge tank. A centrifugal pump, actuated by automatic float switches, periodically empties the surge tank and forces the water through a closed pressure sand filter into the clear-water tank. As needed, backwash water is pumped by a centrifugal pump from the clear-water tank through the filters and into the backwash and sludge tank. Filtered water is pumped from the 500-barrel, wooden, clear-water storage tank by an Oilwell P46 pump equipped with porcelain plungers and powered by a 50-hp. motor. High- and low-pressure switches protect the pump against excessive pressure, and floats and electric contacts control the pumping equipment to maintain a constant supply of treated water. Table 3 shows the mineral analyses of raw and treated water. The plant pressure on March 1, 1957, was 60 p.s.i.

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Results of Flooding

The Bonaventure Oil Corp. pilot project has not been in operation long enough to indicate the effect of water injection on the oil-production rate. Approximately 8,000 barrels of water was injected into the Bartlesville formation during February 1957. A substantial increase in the oil-production rate is anticipated when enough water has been injected.

TABLE 3. - Mineral analyses of injection waters, Bonaventure Oil Corp. Karns project, Washington County, Okla.

	Supply-well water		Aerated brine		Clear well water	
Radical	p.p.m.	Reacting values, percent (Palmer)	p.p.m.	Reacting values, percent (Palmer)	p.p.m.	Reacting values, percent (Palmer)
Calcium (Ca)	4,600	6.30	4,400	6.01	4,600	6.36
Magnesium (Mg)	1,540	3.46	1,500	3.38	1,400	3.19
Sodium (Na)	33,900	40.24	34,100	40.61	33,600	40.45
Carbonate (CO_3)	0	0	0	0	0	0
Bicarbonate (HCO_3)	414	.19	359	.16	164	.08
Sulfate (SO_4)	72	.04	87	.05	97	.05
Chloride (Cl)	63,900	49.77	64,800	49.79	63,800	49.87
Total solids	105,146	100.00	105,246	100.00	103,497	100.00
Hydrogen sulfide (H_2S)	Present		None present		None present	
Barium (Ba)	39 p.p.m.		38 p.p.m.		21 p.p.m.	
Specific gravity, 60° F.	1.069		1.067		1.067	

Summary of Operations

Bonaventure Oil Corp. Karns project
Washington County, Okla.

Location - sec. 8, T. 27 N., R. 14 E.
Sand flooded - Bartlesville.
Depth to top of sand - 1,130 feet.
Average sand thickness - 20 feet.
Area flooded - 30 acres.
Well pattern - 5-spot (660 x 660 ft.).
Type of water - brine.
Type of system - open.
First water injected - February 1957.
First oil increase - none.
Status - active.
Gravity of oil - 36° API.
Viscosity of oil - 3.3 cp. at 100° F.

Primary production data

(Not available.)

Summary of waterflood performance

Date	Acres flooded	Active input wells	Active oil wells	Oil recovery, bbl. per acre	Cumulative water-injected: oil-produced ratio
March 1, 1957	30	8	11	Testing	Testing

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Signal Oil & Gas Co. Flood 3 Project

The Signal Oil & Gas Co. began operations on its Flood 3 project in October 1956 with a pilot flood of 30 acres on the Miller lease in sec. 7, T. 27 N., R. 14 E., in the Wayside field, Washington County, Okla. The entire project includes 416 acres in secs. 7 and 18, T. 27 N., R. 14 E., but the immediate concern is the pilot operation on the Miller lease. Figure 11 shows the location of wells on the Miller lease and primary-production data.

The formation flooded is the Wayside sand, which is at an average depth of 440 feet and has an average thickness of 20 feet. Analyses of cores before flooding had the following average characteristics: Porosity, 18 percent; permeability to air, 25 millidarcies; effective permeability to water, 2.5 millidarcies; oil saturation, 35 percent; and water saturation, 45 percent. Results of a representative core analysis are shown in figure 12. The produced oil has an API gravity of 29.2°.

History Before Flooding

Initial drilling on the project was begun in 1908 and continued through 1910 and 1911. Oil was produced principally by primary methods, although gas injection was tried. The primary production (see fig. 11) was estimated from partial-production records and initial oil-production rates of the wells completed during that period. Available production records do not distinguish between production from a few wells in the Bartlesville sand and numerous wells in the Wayside sand. Gas injection and additional drilling increased production rates in the late twenties and early thirties. Waterflooding was begun on October 15, 1956, when 6 input wells and 3 new oil wells were completed on the pilot-flood pattern.

Method of Completing and Operating Wells

All new wells were drilled by a rotary, using air as the circulating medium. Approximately 35 feet of 7-inch drive pipe was set and cemented to the surface in each of the wells. A 6-1/4-inch hole then was drilled to the top of the sand, and the producing formation was cored with a diamond bit. Analyses and visual examination of the cores aided in selecting the setting point of the casing. Each well was shot with approximately 2 quarts of liquid nitroglycerin per foot of pay sand and then was cleaned out with air. The 4-1/2-inch pipe was set on a formation packer and cemented to the surface. The cement plug was drilled out and again the well was cleaned out. One of the input wells was converted from a core-test well drilled by the former owner; the well was cleaned out with approximately 50 gallons of mud acid, which was agitated by the bailer to clean the sand face thoroughly before the acid was bailed from the well.

Each input well was equipped with a conventional waterflood-type meter and control valves; and upstream from the meter a Cuno strainer having a 25-micron, plastic-bonded felt filter. The water-distribution system consists of plain pipe with Victaulic couplings. The main line is 2-inch pipe, and the lateral lines are 1-inch pipe.

Each oil well is equipped with 2-inch tubing and 5/8-inch rods and a working barrel is set opposite the sand face. Surface equipment on new wells consists of individual pumping units powered by 2-hp. electric motors. Automatic starters and timers control the pumping. Oil lines of 1-1/2-inch plastic pipe are connected from each of the producing wells into a manifold system, which enables the operator to segregate individual wells for testing.

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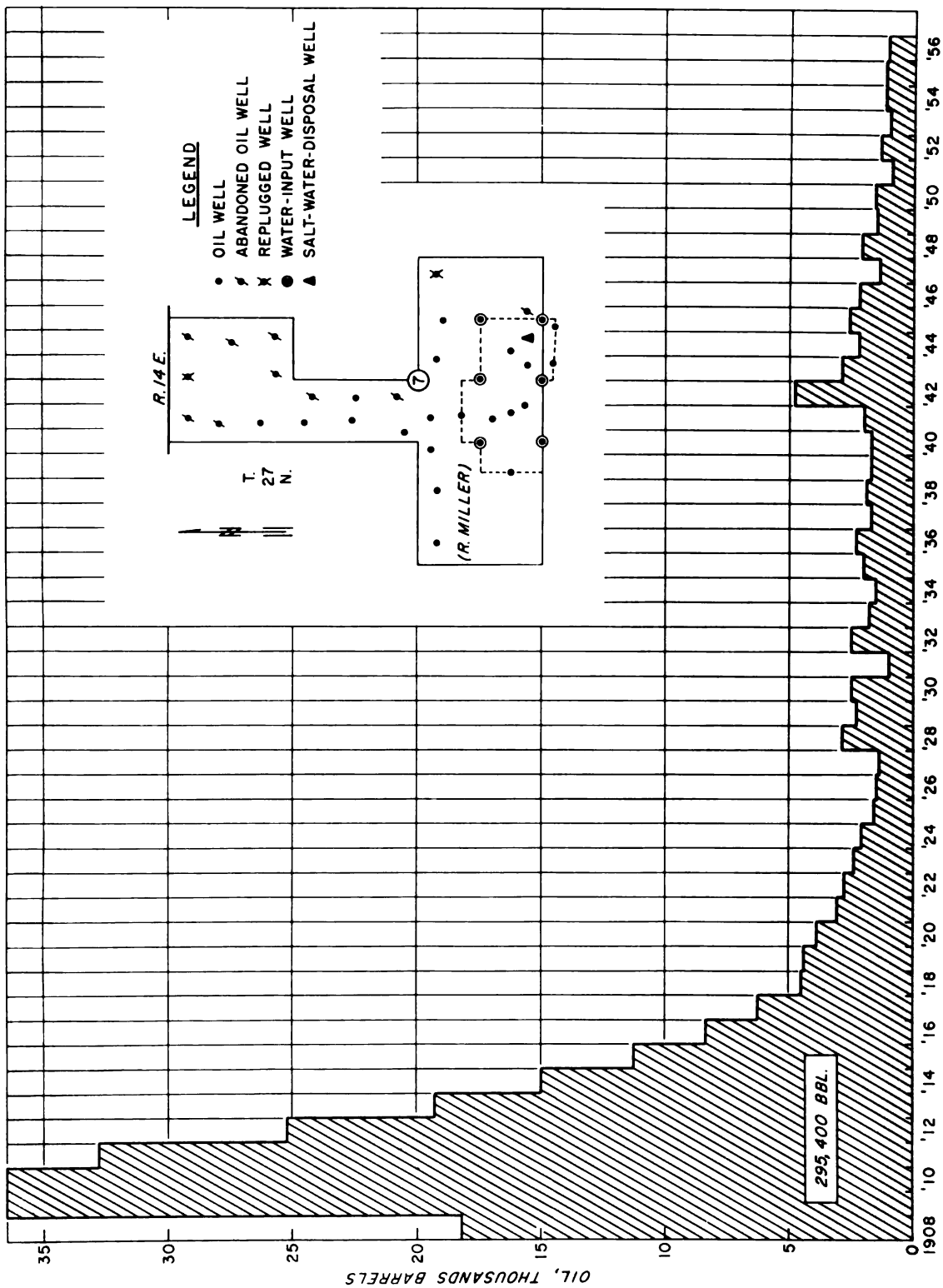

Figure 11. - Production history and map of Signal Oil & Gas Co. Flood 3 project, Miller lease, Washington County, Okla., Jan. 1, 1957.

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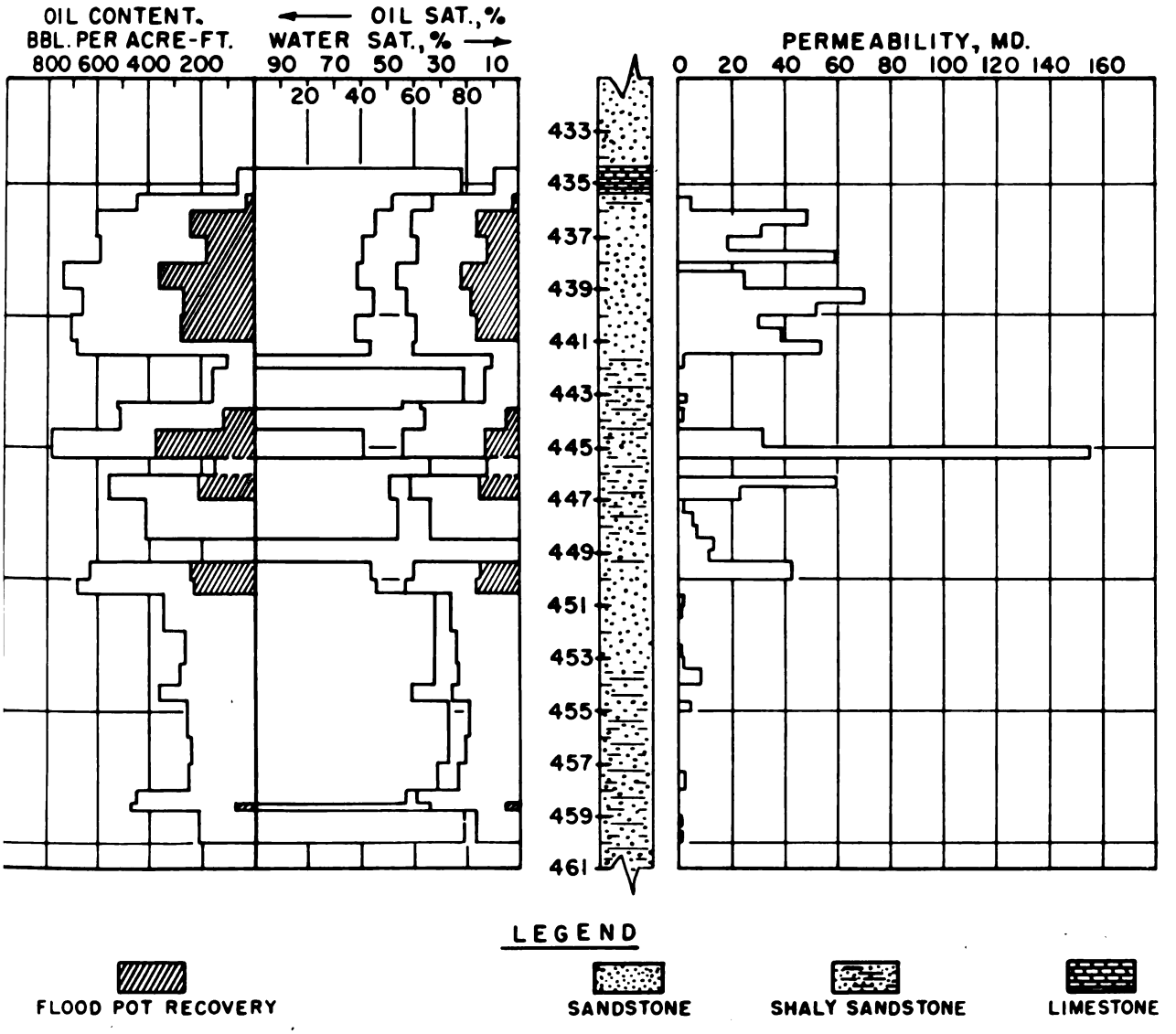

Figure 12. - Representative core analysis of Wayside sand, Signal Oil Co. Flood 3 project, Wayside field, Washington County, Okla.

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Produced brine will not be handled in the system but will be injected into a separate brine-disposal well.

Source and Treatment of Water

Brine for flooding is obtained from a supply well completed at a depth of 2,438 feet in the Arbuckle limestone. The well was completed with 8-5/8-inch casing set and cemented at 1,769 feet at the top of the Arbuckle and 642 feet of 7-inch liner set and cemented at a depth of 2,308 feet. The well was shot and completed in the water-bearing sand section of the Roubidoux formation from 2,340 to 2,400 feet. The static water level in the well is approximately 220 feet. The well is pumped by a Peerless Hi-Lift, helical, positive-displacement pump suspended on 326 feet of 3-inch tubing and powered by a 15-hp. Allis Chalmers electric motor. A tailpipe of 221 feet of 2-7/8-inch Fibercast is used below the pumping element. A small Proportioner chemical-feed pump injects daily about 1-1/2 pints of Orchem 922 special corrosion inhibitor through a 3/8-inch plastic pipe at a depth of 500 feet into the bottom of the Fibercast tailpipe. The small-diameter plastic pipe is suspended in the annulus of the well alongside the 3-inch tubing.

An unusual feature of this project is the compact portable treating and pumping unit, which was designed especially for small pilot-waterflooding tests. The various parts are skid-mounted and can be transported readily from one test site to another. The treating, filtering, and pumping unit also contains a motor-generator plant for use should the outside power fail. Other units, such as a warehouse, a laboratory, and tanks, are handled separately; but each can be loaded onto a large truck. Figure 13 is a drawing of the pilot treating plant.

The Arbuckle brine is pumped into a 130-barrel steel tank that serves as a raw-water storage tank. The main waterline from the well is connected into a standpipe on which two Murphy float switches control the off-on operation of the pump to maintain an adequate volume of raw water in the storage tank. Brine is drawn from this tank and pumped to the filter by a 1- by 2- by 6-inch, Peerless, centrifugal changing pump, coupled to a 3-hp., 220-volt, 3-phase electric motor. A slurry of diatomaceous earth mixed with fresh water in a Fiberglas tank is injected continuously into the raw water, as passed to the filter, by a 5/8-inch Madden diaphragm slurry pump direct-connected to a 1/4-hp. electric gear motor. Fresh water from a surface pond is pumped by a Montgomery Ward jet pump, which is powered by a 1/2-hp. electric motor and has a pressure switch and a 15-gallon tank. The filter has an effective area of 75 square feet and a rated capacity of 2,500 barrels daily. It was custom-built with a Monel shell and core and has 8 Fiberglas leaves, 29-1/2 inches in diameter, covered with Saran cloth bags. The filter is equipped with a 1/2-hp. electric gear motor for rotating the leaves during backwashing. The central panel is operated electrically and automatically regulates the flow of influent and slurry during backwashing operations. The filter cake is removed by rotating the filter leaves past fixed jets of clear water. Sludge drops to the bottom and is discharged into a backwash pond.

The control panel has two pressure gages, a pressure recorder, a 7-day time clock, which controls the 9 automatic-recycling circuits, and circuit breakers for all electrical circuits. Mounted behind the panel are two low-water cutoff switches and several pressure switches for the tanks and pumps and a Kates flow regulator for the filter discharge. Figure 14 is a schematic flow diagram of the treating unit.

Filtered water is pumped into the other 130-barrel tank and from there to the input wells by a Gaso 1-3/4- by 3-inch horizontal triplex pump having Monel plungers

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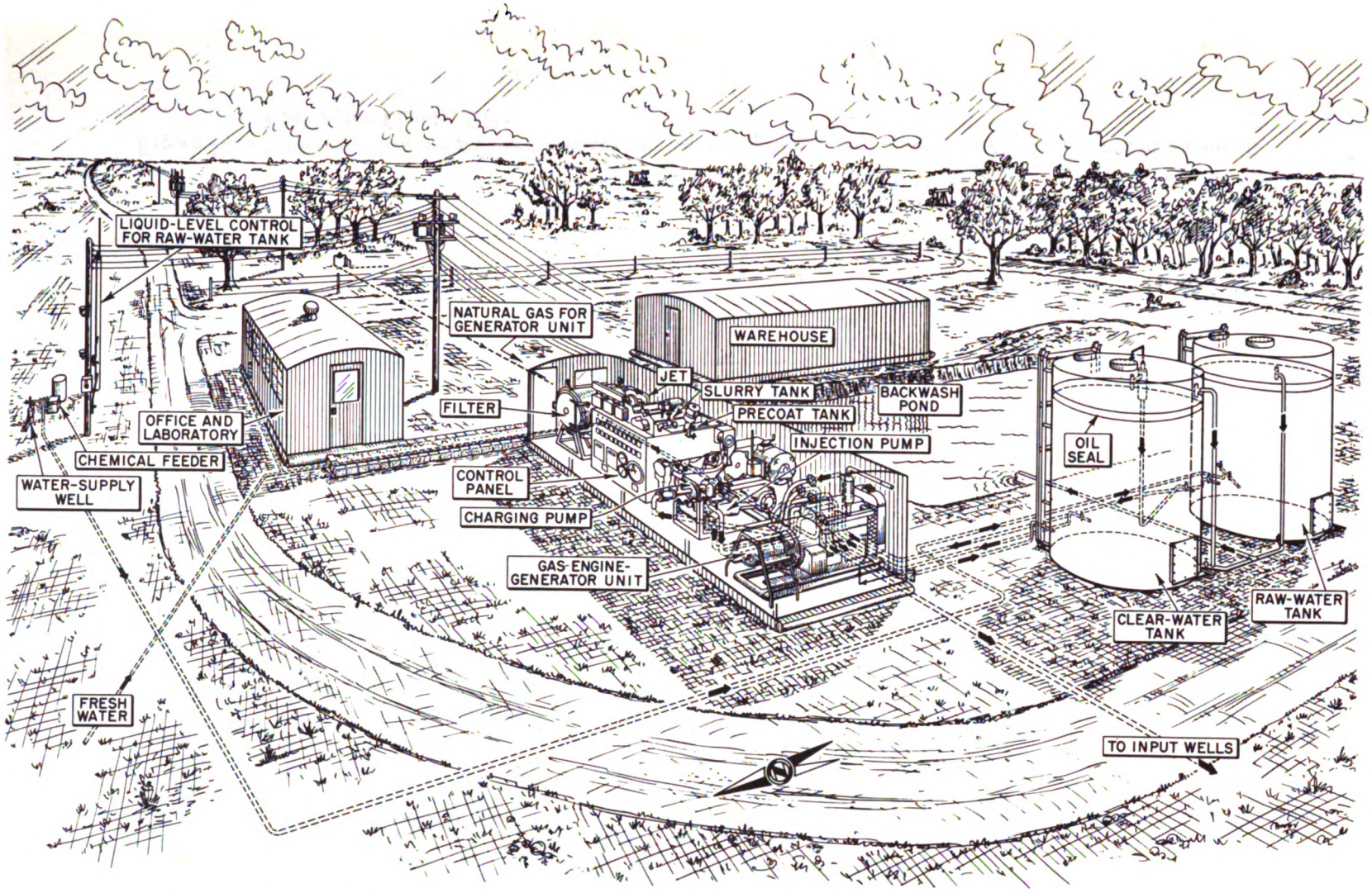

Figure 13. - Water-treating plant of Signal Oil & Gas Co. Flood 3 project, Washington County, Okla.

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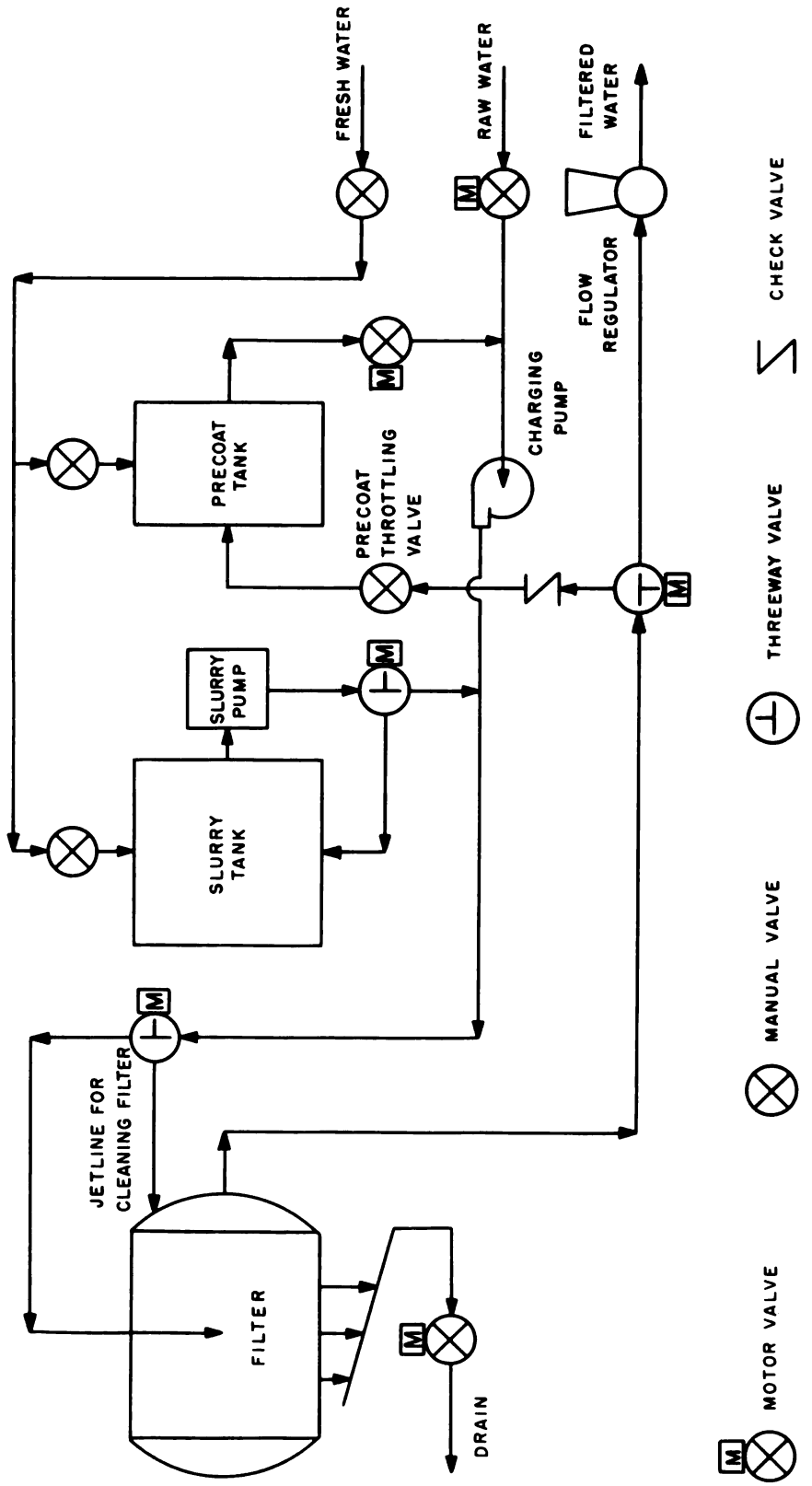

Figure 14. - Schematic flow diagram of filter system, water-treating plant, Signal Oil & Gas Co. Flood 3 project, Washington County, Okla.

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and a bronze fluid end. The pump is belt-driven by a Varidrive unit powered by a 10-hp. electric motor above the pump. The operating pressure at the plant is about 250 p.s.i. A corrosion inhibitor is added in the slurry tank to minimize corrosion in the water-distribution lines, and an oil seal protects the water is both the raw- and clear-water tanks.

The results of mineral analyses of water samples from the system are shown in table 4. A well-equipped laboratory in the field office enables the plant personnel to make daily tests to maintain good water control.

Results of Flooding

The Signal Oil & Gas Co. Flood 3 project has not been in operation long enough to indicate the effect of water injection on the oil-production rate. From October 16, 1956, to February 1, 1957, approximately 17,650 barrels of water was injected (an average of 2,942 barrels per well). While the reservoir is being filled, several wells in the pattern or adjacent to it are being pumped to maintain oil production and to test for effects of the water drive.

TABLE 4. - Mineral analyses of injection waters, Signal Oil & Gas Co. Flood 3 project, Washington County, Okla.

	Supply-well water		Filtered, treated water	
Radical	p.p.m.	Reacting values, percent (Palmer)	p.p.m.	Reacting values, percent (Palmer)
Calcium (Ca)	8,000	7.78	8,000	7.64
Magnesium (Mg)	2,100	3.36	2,200	3.46
Sodium (Na)	45,900	38.86	46,800	38.90
Carbonate (CO_3)	0	0	0	0
Bicarbonate (HCO_3)	213	.07	213	.07
Sulfate (SO_4)	37	.01	53	.02
Chloride (Cl)	90,900	49.92	92,500	49.91
Total solids	147,150	100.00	149,766	100.00
Hydrogen sulfide (H_2S)	Present		Present	
Barium (Ba)	33 p.p.m.		29 p.p.m.	
Specific gravity, 60° F.	1.100		1.100	

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Summary of Operations

Signal Oil & Gas Co. Flood 3 project
Wayside field, Washington County, Okla.

Location - sec. 7 and 18, T. 27 N., R. 14 E.
Sand flooded - Wayside.
Depth to top of sand - 440 feet.
Average sand thickness - 20 feet.
Productive area - 416 acres.
Area flooded - 30 acres.
Well pattern - 5-spot (660 x 660 ft.).
Type of water - brine.
Type of system - closed.
First injection - Oct. 15, 1956.
First oil increase - none.
Status - active.
Gravity of oil - 29.2° API.
Viscosity of oil - 37 cp. at 60° F.

Oil production, by years, bbl.
(Miller lease, 160 acres)

1908 ..... 1/18,250	1921 3,194	1934 1,563	1947 1,463
1909 ..... 1/36,500	1922 2,835	1935 2,073	1948 2,129
1910 ..... 1/36,500	1923 2,410	1936 2,325	1949 1,596
1911 ..... 1/32,800	1924 2,144	1937 1,794	1950 1,690
1912 ..... 1/25,200	1925 1,672	1938 1,945	1951 985
1913 ..... 1/19,300	1926 1,514	1939 1,788	1952 1,423
1914 ..... 1/15,000	1927 1,474	1940 1,784	1953 1,038
1915 ..... 1/11,300	1928 2,992	1941 2,038	1954 1,244
1916 ..... 1/ 8,400	1929 2,392	1942 4,874	1955 1,239
1917 6,360	1930 2,560	1943 2,945	1956 2/ 1,167
1918 4,522	1931 1,009	1944 2,260	
1919 4,463	1932 2,517	1945 2,691	
1920 3,924	1933 1,859	1946 2,246	

1/ Estimated from partial-production record and initial-production rates.
2/ Waterflooding begun.

	Bbl.
Oil recovery by primary methods (160 acres)	295,391
Recovery per acre by primary methods (135 productive acres)	2,185
Water injected to February 1, 1957	17,650

Summary of waterflood performance

Date	Acres flooded	Active input wells	Active oil wells	Oil recovery, bbl. per acre	Cumulative water-injected: oil-produced ratio
February 1, 1957	30	6	9	(Testing)	(Testing)

Monthly record of water injected and oil produced, bbl.

	1956		1957	
	Water injected	Oil produced	Water injected	Oil produced
January			3,830	-
October	1,800	-		
November	3,414	-		
December	8,606	-		
Total	13,820	-	3,830	-

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Fred P. Schonwald Morrison Project

In September 1956 a new waterflooding test of the Peru-sand formation of Washington County, Okla., was begun with injection of water into 20 wells. The pilot-flood area includes about 52 acres in sec. 4, T. 25 N., R. 13 E., in the Bartlesville field and is a small part of the 470-acre project. The 12 oil wells and the input wells were drilled at the same time; however, production from the oil wells has been delayed. The reservoir pressure is increased as indicated by a rise in the fluid levels in the wells. Figure 15 is a map showing the location of the wells in the pilot area.

The formation in that area is at an average depth of 600 feet and has an average thickness of 40 feet. As much as 70 feet of the Peru sand was drilled for some wells. The sand appears to be "clean"; it has a few shale laminations and a fairly uniform permeability profile. The porosity is about 18 percent. The gravity of the stock-tank oil is 38° API, but apparently some gas is still in solution in the reservoir oil.

History Before Flooding

Primary oil production from the leases being flooded dates back to 1906, when several wells were completed. Since then, drilling has been continuous, a few additional wells being completed each year. Air or gas injection was begun in the late twenties and continued until 1942. The first waterflooding test was begun in November 1949 by a former owner, when fresh water from nearby Fish Creek was injected into four old converted oil wells that had been reconditioned as input wells. Water was injected sporadically, as the water supply was low because of a drought. The rate of production from the single producing well in the center five-spot pattern eventually was increased somewhat by water injection. This project was abandoned temporarily when the leases were purchased by Fred P. Schonwald for a full-scale pilot test.

Method of Completing and Operating Wells

All the new wells on the pilot project (begun in September 1956) were drilled by a rotary, using air as the circulating medium. Wells were completed by setting and cementing a section of 8-1/2-inch drive pipe from 20 to 30 feet long in each well. The well then was drilled with a 6-1/4-inch bit to the top of the producing formation, where the hole was reduced to provide a shoulder for setting pipe or a packer. The productive formation was drilled and shot with 1 to 2 quarts of liquid nitroglycerin per foot of sand. The well then was cleaned out and the pipe set. In each of the input wells 2-inch plain steel pipe was set on a flange-type packer and cemented with 30 to 40 sacks of cement. In each of the oil wells 4-inch pipe was set on the shoulder at the top of the sand and cemented with 10 to 15 sacks of cement.

Surface equipment at each input well consists of a meter and control valves, which regulate the input rate into the well.

Each producing oil well will be equipped with an electrically powered pumping unit.

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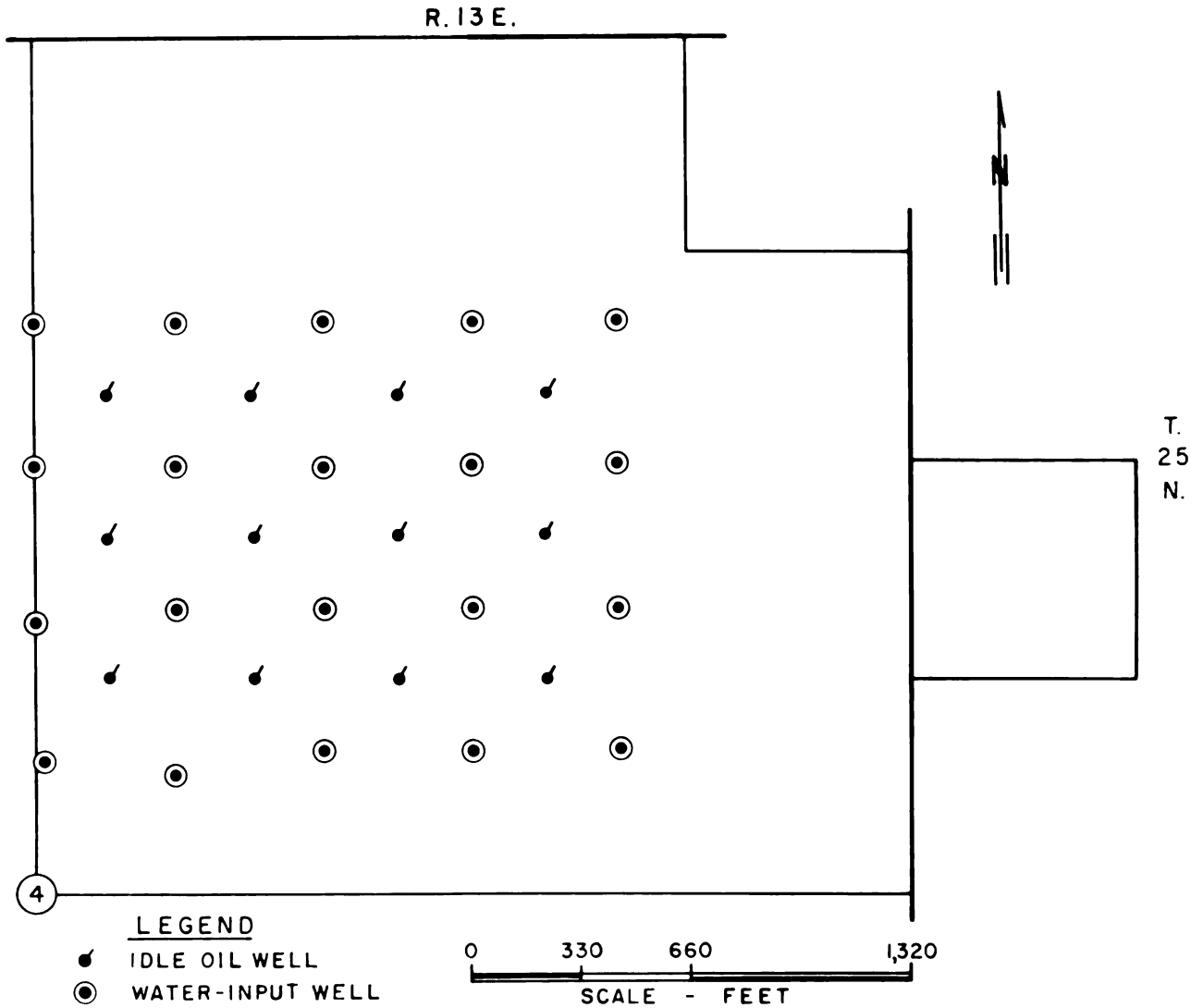

Figure 15. - Pilot-flood area, Fred P. Schonwald Morrison project, Bartlesville-Dewey field, Washington County, Okla., Feb. 1, 1957.

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Source and Treatment of Water

When the project was begun, fresh water from several shallow wells along the banks of nearby Fish Creek was used for flooding. However, the supply from this source proved inadequate, and a well was drilled into the Arbuckle formation to obtain a larger and more reliable supply. The Arbuckle well was drilled to a total depth of 2,345 feet (about 15 feet into the granite), and 7-inch pipe was set at 1,693 feet and cemented to the surface. A good supply of water is provided if the static fluid level is at 170 feet below ground level. Brine is lifted through 3-inch steel tubing by a 20-hp. submersible electric pump set at a depth of approximately 1,000 feet; then is pumped to the aeration pond through 4-inch pipe, which empties into a wooden trough. The brine flows from the trough through many small orifices, which provide some aeration, then into the pond over a step-type aerator, and from the aerating pond flows by gravity into a mixing tank, where chemicals are added. Here a solution of sodium polyphosphate is proportioned continuously into the raw water to stabilize it, and solid sodium polyphosphate balls are dissolved in a small tank by a stream of treated water pumped from the plant through 1/2-inch-diameter pipe. A separate, small, electrically powered pump periodically injects a quantity of corrosion inhibitor and germicide into the brine at the mixing tank. Each chemical is fed in proportion to the quantity of water used for injection purposes. Figure 16 is a drawing of the water-treating plant.

From the mixing tank the water flows into a combination settling and storage pond (170 by 70 by 18 feet) equipped with 2 "end-around" baffles of cement-asbestos sheeting fixed to wooden posts.

A centrifugal pump coupled to a 5-hp. electric motor pumps the water from the settling pond into a 1,000-barrel covered wooden storage tank. A 2-1/2- by 3-inch centrifugal pump coupled to a 3-hp. electric motor forces the water from the supply tank through a closed pressure sand filter into another 1,000-barrel clear-water storage tank. A 4- by 5-inch centrifugal pump, coupled to a 7-1/2-hp. electric motor, is used to backwash the filter when it is necessary. Backwash water from the filter is discharged into a separate backwash pond, which also serves as a preliminary skimming pond for the produced brine from the tank battery and is connected to the aeration pond. Table 5 shows the results of analyses of brine samples taken at various points in the system.

Injection water is pumped to the input wells at a plant pressure of 380 p.s.i. by 5-1/2- by 10-inch horizontal duplex pump belted to a 50-hp. electric motor. In February 1957 the plant was not operating at full capacity, so the injection pump was equipped with 4-inch liners and the motor was wired to develop only 24 hp. The pump is equipped with low- and high-pressure automatic switches, and liquid-level switches act to control the pumps and maintain a supply of water.

Results of Flooding

The F. P. Schonwald Morrison project has not been in operation long enough to indicate the effect of water injection. When fluid-level measurements in the oil wells indicate a pressure buildup in the formation, pumping equipment will be installed on the wells. To February 1957 approximately 105,000 barrels of water (an average of 5,250 barrels per well) had been injected into the formation.

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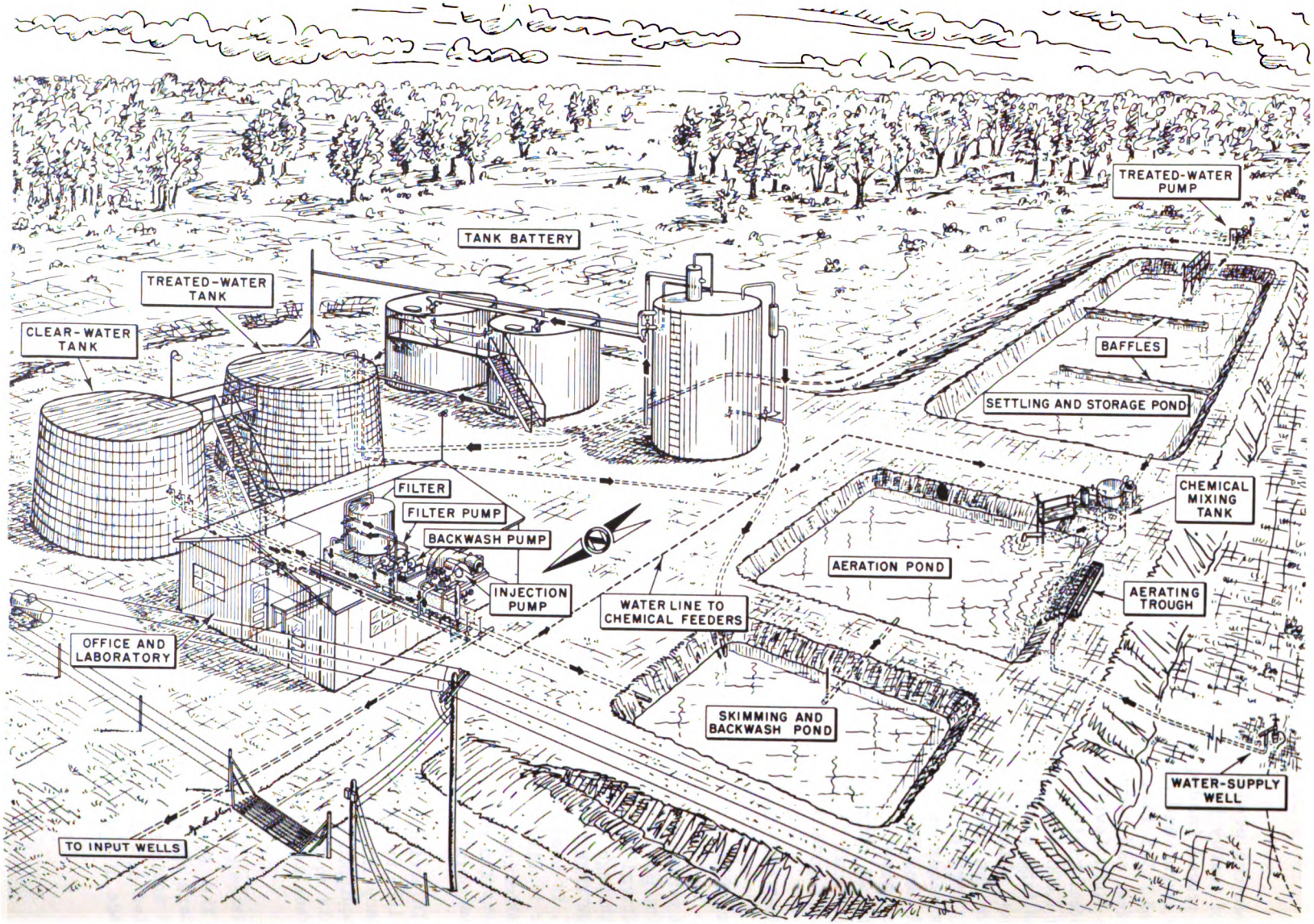

Figure 16. - Water-treating plant of Fred P. Schonwald Morrison project, Washington County, Okla.

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TABLE 5. - Mineral analyses of injection waters, Fred P. Schonwald Morrison project, Washington County, Okla.

Radical	Supply-well water		Aerated brine		Clear well water	
	p.p.m.	Reacting values, percent (Palmer)	p.p.m.	Reacting values, percent (Palmer)	p.p.m.	Reacting values, percent (Palmer)
Calcium (Ca)	7,300	6.76	7,500	8.20	7,600	8.19
Magnesium (Mg)	1,800	3.36	1,900	3.42	1,900	3.37
Sodium (Na)	40,300	39.88	40,300	38.38	40,900	38.44
Carbonate (CO_3)	0	0	0	0	0	0
Bicarbonate (HCO_3)	280	.10	262	.09	262	.09
Sulfate (SO_4)	48	.19	0	0	0	0
Chloride (Cl)	79,800	49.81	80,800	49.91	81,900	49.91
Total solids	129,528	100.00	130,762	100.00	132,562	100.00
Hydrogen sulfide (H_2S)	Present		None detected		None detected	
Barium (Ba)	Trace		25 p.p.m.		25 p.p.m.	
Specific gravity, 60° F.	1.095		1.094		1.094	

Summary of Operations

Fred P. Schonwald Morrison project
Fish Creek pool, Washington County, Okla.

Location - sec. 4, T. 25 N., R. 13 E.
Sand flooded - Peru.
Depth to top of sand - 600 feet.
Average sand thickness - 40 feet.
Productive area - 470 acres.
Area flooded - 52.
Well pattern - 5-spot (440 x 440 ft.)
Type of water - brine.
Type of system - open.
First water injected - Sept. 7, 1956.
First oil increase - none.
Status - active.
Gravity of oil - 38° API.
Viscosity of oil - 6.8 at 77° F.

Primary production data

(Not available.)

Summary of waterflood performance

Date	Acres flooded	Active input wells	Active oil wells	Oil recovery, bbl. per acre	Cumulative water-injected: oil-produced ratio
February 1, 1957	52	20	-	(Testing)	(Testing)

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